ISSN 0840-8440

OLOGY TRANSFER CONFERENCE • 1988

ISSN 0840-8440

PROCEEDINGS

TECHNOLOGY TRANSFER CONFERENCE 1988

November 28 and 29, 1988

Royal York Hotel

Toronto, Ontario

SESSION E
ENVIRONMENTAL ECONOMICS

Sponsored by
Research and Technology Branch
Environment Ontario
Ontario, Canada

Introduction

Environment Ontario holds its annual Technology Transfer Conference to report and publicize the progress made on Ministry-funded projects. These studies are carried out in Ontario Universities and by private research organizations and companies.

The papers presented at Technology Transfer Conference 1988 are published in five volumes of conference Proceedings corresponding to the following sessions:

- SESSION A: AIR QUALITY RESEARCH
- SESSION B: WATER QUALITY RESEARCH
- SESSION C: LIQUID AND SOLID WASTE RESEARCH
- SESSION D: ANALYTICAL METHODS
- SESSION E: ENVIRONMENTAL ECONOMICS

This volume is comprised of presentations given during Session E of the conference.

For reference purposes, indices for sessions A,B,C and D may be found at the back of this volume, listed in alpha-numeric order.

For further information on any of the papers, please contact either the authors or the Research and Technology Branch at (416) 323-4574 or 323-4573.

Acknowledgements

The Conference Committee would like to thank the authors for their valuable contributions to environmental research in Ontario.

Disclaimer

The views and ideas expressed in these papers are those of the authors and do not necessarily reflect the views and policies of Environment Ontario, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

INDEX

Abstract | Page

SESSION E: ENVIRONMENTAL ECONOMICS

Oral Presentations

Abstract Page

SESSION E: ENVIRONMENTAL ECONOMICS

Poster Presentations

KEYNOTE PAPER I

Science-Based Innovation

Science-based innovation is critical in today's global economy to sustain and enhance a nation's prosperity. In seeking to sustain and enhance its prosperity by participating in a growing volume of world trade, large and small economies, face critical problems of adapting their institutions, policies and practices to a radically new environment. Key elements of this environment are that world trade now occurs in a global economy in which the interweaving of science, engineering and technology has acquired the power to transform the comparative advantage and prosperity of nations. With the scale, scope and openness of the international enterprise of science, the transferability of technologies and the mobility of capital, science-based innovation has become a driving force for the technological and corporate change that creates new tradeable goods and services. These conditions are radically different from those of the Industrial Revolution.

In a modern economy the sector which produces tradeable goods and services supported by the first service sector of financial, legal, energy, transportation, communication systems, etc., generates the income that enables a country to invest in the second service sector of education, health care and other personal and social benefits. (Figure 1). In some countries financial institutions have been operating in a manner that hampers the developments in the tradeable goods and services sector.

To participate in the global economy driven by science-based innovation it is essential that, on a national or regional basis, the pyramid of research capacity (in terms of knowledge flow) that leads to tradeable products and services has integrity, that is, that there be a reasonable balance of capacity throughout the pyramid. (Figure 2).

Increasingly science-based innovation requires a strong long-term applied research capacity, particularly in relation to emerging generic technologies, that is industry-based and controlled. This capacity has to be linked to a high quality fundamental research base and a strong market focused development capability.

Large and small countries in different stages of development faces problems in;

i) achieving structural integrity necessary for science-based innovation suitable for their limited resources of people and money, and

ii) using their limited resources effectively.

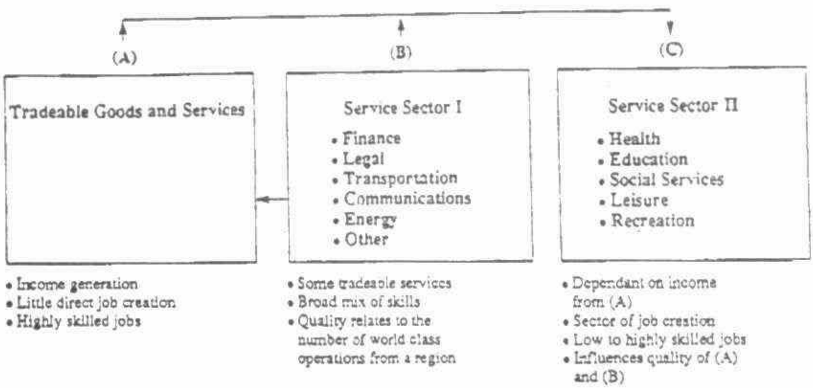


Figure 1: A Simple Model of the Economy

In today's global economy it is important to understand the relationship between innovation in the production of tradeable goods and services and the generation of income. A simple model in terms of stating the key issues is given in Figure 1. This model segments the economy into three blocks labeled (A) Tradeable Goods and Services, (B) Service Sector I and (C) Service Sector II. The major source of income which sustains our standard of living comes from sector (A) Tradeable Goods and Services. Canada's current standard of living requires very substantial volumes of trade into world markets. In the globally competitive market of today a nation must be concerned with maintaining and enhancing the environment it creates for business and industry that can innovate in the production of tradeable goods and services. To function effectively, such enterprises require a high quality service sector, namely (B) Service Sector I, comprising such services as finance, legal, energy, construction, communications, transportation, distribution. It is the combination of this business service sector (which produces some tradeable services) and the sector directly producing tradeable goods and services which generate the primary income of a region.

It is the income generated by the foregoing activities which allows the expansion of (C) Service Sector II that is concerned with personal and social services. The social service sector includes health care, education, community services, leisure and recreational activities. Our capacity to sustain and improve the services and opportunities depends on the capacity of sectors (A) and (B) to generate the necessary income.

The Science-Based Pyramid of Research

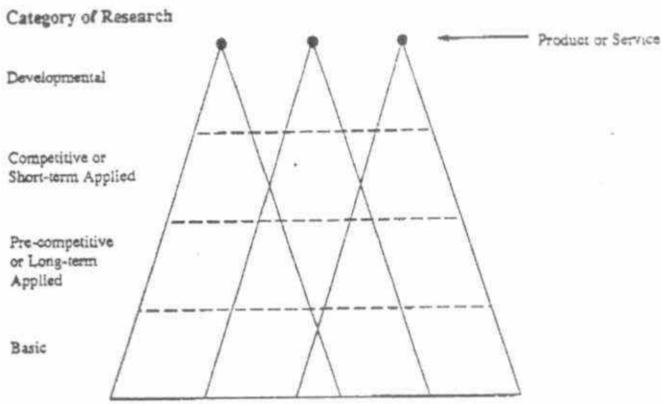


Figure 2

Research as an element related to the overall process of innovation, can be broken down into three primary components that must be linked together to be effective:

1. Basic or fundamental research which is usually characterized by the researchers' primary objective being the generation of new knowledge and understanding about man and the world around us. This research is long-term (usually on a time-scale of 10 years or more), and has a high level of uncertainty in terms of what the results will be. In Western culture, basic research is primarily university-based and seldom results in knowledge that is of immediate commercial value. The knowledge gained from such research is rapidly and widely distributed to scientists throughout the world through publication in scientific journals. Because the results from this research are, or have been, considered a public good, this type of research has been financed primarily by the public sector and private benefactors. Increasingly, however, when knowledge contributed by basic research is critical for new product development, industries are becoming involved in basic research (OECD, 1987).

2. Applied research: In most countries, applied research is mainly carried out in industrial or government laboratories, but in some countries, there is substantial university involvement with respect to longer term research, particularly in schools of engineering, medicine and management. Applied research has a strategic target and attempts:

- to extend the scope of understanding of materials and processes,

- to determine how the accumulated knowledge from basic research, extend where necessary by focused specialized research, can be used to develop a potential new product or services, or

- to determine how to modify and improve the performance of existing products or services to sustain their marketability.

Applied research which is medium to long-term (on a time scale of three to ten years), also has a significant level of uncertainty, but because it is targeted, there is a probability that there will be economic benefit. The means for the financing of this research vary. In some sectors such as the pharmaceutical and chemical fields, the research is largely funded by the private sector primarily through the benefits from patent protection, whereas in fields such as aircraft and electronics, there has been a mixture of public and private financing. In some cases a monopoly position (e.g. AT&T and Bell Laboratories) has encouraged the funding of longer-term applied research, but there are few examples of the private sector being able to finance longer term applied research wholly from its own resources unless there is effective patent protection or the business has a monopoly position.

It is common in some sectors to associate the processes of engineering design and development of a product or service as discussed above, with the term development or developmental research.

3. Developmental research is research that:

- makes use of the fruits of applied research specifically to create a new marketable product or service, or

- improves, through a series of small steps of innovation based on state-of-the-art knowledge, an already existing product or service, or

- enhances the ease of production of a product or the provision of a service.

This type of research has the least uncertainty, is carried out on a time scale of less than three years, and has the highest probability of economic benefit. Developmental research is mainly financed by the private sector, although there are exceptions in which there has been substantial public financing.

The foregoing categories of research can be represented by the pyramids shown in Figure 2. At the narrow peak of each pyramid is a product or service, a specific artifact of technology designed to perform a particular function in a market. From its peak each pyramid expands through the three primary categories of research to a broad base in basic research. The category "applied research" has been segmented into two slices labeled competitive (short-term applied) and pre-competitive (long-term applied). Competitive applied research is that which has direct proprietary value to the business. Pre-competitive applied research is that which is generally useful in sectors of industry (This research is often concerned with what can be called generic technology). The relative width of each slice across the pyramid suggests the range of generality of the knowledge associated with it. The overlapping of parts of the pyramids indicates that as one reaches towards the scientific roots pertinent to the development of a particular product, the knowledge base becomes relevant to a range of products. Indeed, the essence of basic science is that it seeks for general principles of understanding within particular circumstances of study, whereas engineering, through the technology it creates, seeks to realize a particular operational function in a market within the domain of possibilities bounded by science.

Science-based innovation then is innovation in which the realization of an effective and competitive product or service utilizes, through the focusing processes of the pyramid of research, the full range of scientific and engineering understanding pertinent to the function of the product or service in the marketplace.

The classification of levels of research in the research pyramid of Figure 2 is based on the diverse literature on innovation. Its pertinence for older, large-scale, science-based industries is clear. However, a key point today is that the research pyramid is relevant to all industry participating in the global economy of science-based innovation.

Copies of "INNOVATION AND CANADA'S PROSPERITY: THE TRANSFORMING POWER OF SCIENCE, ENGINEERING AND TECHNOLOGY" may be obtained by filling out the attached form.

KEYNOTE PAPER II

DERIVING BENEFITS FROM ENVIRONMENTAL RESEARCH

Stuart L. Smith, M.D.
President
RockCliffe Research and Technology Inc.
November 1988

As difficult as research can be, it is still more difficult to apply it swiftly for economic or social benefit. In addition to the usual obstacles to technology transfer, environmental research faces additional ones of a political nature. It behooves us to know a great deal more about how research is transformed into practical benefits and how environmental research in particular can be more rapidly applied. The improvement of the environment is an area where, with appropriate policies, economic and social benefits occur simultaneously.

In supporting research activities, we cannot take for granted that application will naturally follow any improvement in knowledge. More attention needs to be paid to the incentive structures of research organizations, the relationship to our industrial sector, and the interaction with political decision-making. By acting now in some specific areas, we can help guarantee that today's research will produce timely and tangible results.

SESSION E

ENVIRONMENTAL ECONOMICS
Oral Presentations

ENVIRONMENT ONTARIO PAPER

ENVIRONMENTAL ECONOMICS: CURRENT STATUS AND FUTURE RESEARCH NEEDS

A. Castel, Corporate Resources Division, Environment Ontario

Environmental protection has long been held by many people to transcend economic constraints and considerations. Pollution was perceived to be a crime against nature and society in which dispasionate economic analysis had no part to play. Moreover, the environmental resources and human health threatened by pollutants were considered to be priceless by many people. The idea that trade-offs could be made between the cost of controls and the achievement of environment goals was widely resisted.

Consequently, none of the environmental statutes that were originally enacted made any mention of economic implications or justification. However, it was soon realized that pollution control would be expensive and that public and private resources available for environmental protection were limited.

By the middle to late 1970's, substantial costs had been incurred by both government and industry for pollution control, clean-up and environmental protection activities. Industrial firms which faced abatement requirements began to complain bitterly about the past and potential costs of pollution control. Business spokespersons, labour groups, politicians and some economists warned that North America faced direct tradeoffs between the environment and jobs or between compliance with requirements and plant closures.

When these complaints and, in some cases, threats of closure were first made, environmental agencies usually had little choice but to grant relief, usually in the form of extended compliance schedules.

Moreover, as municipal and industrial pollution control facilities were installed, further increments of abatement were often found to be more expensive to implement, a consequence economists refer to as rising marginal costs. Removal of the last 10% of pollution will sometimes cost more to achieve than the entire previous 90% of pollution reduction.

On the other hand, as industry, municipalities and other agencies directed their efforts toward pollution control, many opportunities were found to reduce operating costs (e.g., lower energy requirements, reduced or cheaper materials inputs), increase productivity, or recover salable by-products. Many firms actually found pollution abatement to be profitable or were able to avoid costly future problems by carrying out environmental assessments of major development projects.

Nevertheless, as environmental requirements were tightened and abatement costs mounted, it became important to promote the application of the least-cost options which would do the job and, in some cases, to determine whether the added benefits of further controls were commensurate with the extra costs.

Economic principles also contributed to policy development and evaluation. Economists have long advocated policy instruments such as effluent charges, tradeable rights schemes and delay penalties which they believed would give polluters a powerful economic incentive to comply with control requirements.

The Ministry began its own economic assessments in the early 1970's. Ministry economists analyzed the economic impacts of projected abatement costs for different industrial sectors and firms and found that both costs and the economic disruptions due to abatement requirements were being overstated in many instances.

Computer tools were developed to assess the range of potential abatement costs and find the least-cost combinations of control technologies to achieve desired environmental objectives at individual plants.

Furthermore, methods were developed to identify, quantify and value the benefits of abatement and protection programs.

By 1979, a major economic program was initiated to complement Ontario's acid rain research efforts. Biophysical effects information was utilized to estimate the damages caused by acid rain and the monetary values associated with these effects. The costs of precursor emission control programs for Ontario sources were analyzed together with their economic implications. Transport co-efficients from long range atmospheric models were utilized in a computational procedure to determine the least-cost configuration of abatement programs in Eastern North America that would achieve specific deposition targets. Results from this "Screening Model" were used in deliberations to reach a federal/provincial agreement concerning acid rain objectives.

Similarly, recent Ministry initiatives such as the MISA program and the proposed revisions to the air pollution control Regulation 308 each have important economic components.

In addition, guidelines were prepared for the Ministry's policy manual which specify the conditions and procedures for conducting economic analyses of the cost impacts of abatement requirements.

By the early 1980's, the role of economics in the Ministry was well established. However, nearly every issue that was investigated raised new questions and identified important

information gaps. It was then that a Socio-Economic component was added to the Research Advisory Committee (RAC) program. Since the inception of this component, the RAC has supported projects on the economics of hazardous waste transport, biotechnology policy, methods to value non-market goods and services, determinants of participation in solid waste source separation and the costs of advanced wastewater treatment methods for metal finishing and plating processes.

Topics for research on economic-environmental linkages are listed under six issues or subject areas:

- quantification and valuation of pollution damages, risks and disruptions;

- determination of the costs of pollution abatement and environmental protection and their implications;

- development of evaluation tools and their application to proposed policies or programs;

- assessments of industries and businesses which develop and manufacture environmental protection technologies, equipment, products and services;

- social implications of environmental contamination and its control;

- development and testing of forecasting, simulation and optimization models.

With respect to the first issue, there is a particular need for application of risk assessment methodologies and the valuation of risk reductions. Interdisciplinary studies are required to develop dose-response relationships which are used to predict environmental effects. Methods to develop reliable inventories of resources at risk are also needed.

Concerning the costs of controls and protection programs, assessments of the technologies and the costs of monitoring, waste treatment, secondary material recovery and process changes in different industrial sectors are needed. Information about the key factors which motivate private sector decisions regarding technology choice and environmental program implementation are of particular interest.

Information about technologies for ground water protection and clean-up and their costs are of particular interest.

Insights about the factors that could allay citizens' fears and anxieties regarding the location of solid waste incineration, processing and disposal sites are needed as well as research that will help expand composting, source separation and other waste-reduction practices.

A variety of computer assisted models have been developed by the Ministry to integrate bio-physical data and relationships with economic information, resource use or preference data, and evaluation frameworks which are based on economic principles. Further applications of these models to the long term sustainability of our rivers and lakes would be useful.

Finally, empirical studies which show how measurable pollution discharges or environmental quality conditions actually affect human uses, activities, expenditures and perceptions are especially needed for use in regulation development and evaluation activities.

It is clear that there are socio-economic aspects concerning virtually every environmental problem or issue. It is also clear that, in the context of the Ministry's RAC program, the Socio-Economic component provides the opportunity to integrate widely disparate bio-physical, social and economic data into policy-relevant frameworks.

November 9, 1988

E1

UNDERSTANDING ENVIRONMENTAL-ECONOMIC INTEGRATION

Peter A. Victor
VHB Research and Consulting Inc.

ABSTRACT

There is accumulating evidence that economic activity has reached a scale sufficient to cause global changes in the environment. The upsurge of interest in environmental-economic integration is a rational response to this situation.

Much of today's conventional wisdom on environmental-economic issues is derived from the work of a few economists who, for 200 years, have been trying to understand the relationships between the economy and the environment. This paper provides an overview of the theories, empirical work and policy prescriptions of these economists from Adam Smith to those of today.

The early economists such as Smith, Thomas Malthus and David Ricardo, concerned themselves with the question of the sustainability of economic growth in a limiting environment. Their pessimistic prognosis earned economics the epithet of the 'dismal science'. J.S. Mill accepted the analysis of his predecessors but was more sanguine about the prospects of life in a stationary economy.

At about the time that Marx was arguing that capitalism contained the seeds of its own destruction, more conventional economists such as Walras were establishing the theoretical foundations of the market system. To do so they made assumptions which effectively isolated the economy from its environment.

In the early part of the twentieth century two writers in particular, concerned themselves with environmental-economic integration. Harold Hotelling established the principles for the optimal rate of depletion of a finite resource. A.C. Pigou observed that economic activity could have unintended effects on third parties which were beyond the control of the market. He chose pollution as an example of these 'externalities' which drive a wedge between the private costs registered in the market and the full 'social costs' of production and consumption. Externalities and social costs have become the analytical focal point for much of the work in environmental economics that continues today.

The decade following World War II saw the first of many attempts to evaluate social costs. At the same time there was a reawakening of interest in the concerns of the early economists: were there sufficient resources to sustain economic growth in the post-war era? The Economics of Conservation written by Canada's A.D. Scott in the nineteen fifties further explored the market incentives for conservation. He stressed the role that prices play in encouraging the conservation of scarce resources. Scott and others also did original work on 'common property' resources, showing that over-fishing was unavoidable under a market system where fishing rights were not protected.

The analyses of Pigou, Scott and others underscored what many non-economists already knew. Left to itself, the market system could not be relied on to protect the environment. Policy intervention by government was required.

Economists argued, as they still do, that the best type of intervention is that which most closely mirrors the workings of the market. Hence, they promote benefit-cost studies that show how an efficient market would work to protect the environment if the structural reasons for its failure to do so did not exist. Economists also advocate the use of tradeable emission rights and emission charges as two ways of achieving environmental objectives in the most economically efficient manner.

Twenty years ago Kenneth Boulding prompted a reconceptualization of environmental-economic integration. He wrote about the econ omics of 'spaceship earth' and emphasised that the earth is a closed system. All materials used in economic activity must eventually be disposed of on Earth. Very quickly economists reformulated the basic, general equilibrium theory of markets developed 100 years earlier by Walras. In doing so they stressed that externalities were all-pervasive and not just occasional exceptions to an otherwise smoothly functioning system. Attempts were made by this author and others to estimate the magnitude of these material flows so that conventional measures of economic activity could be tied quantitatively to the environment.

The next theoretical breakthrough came in 1971 with Georgescu-Roegen's study of the entropy law and the economic process, a difficult work that is still being digested by economic theorists. Economic activity does not merely recycle the earth's resources, it irreversibly degrades them. This could have serious implications for the sustainability of economic growth in the long term.

Most recently, Perrings has produced a work which not only makes Georgescu-Roegen's study a little more transparent, but highlights the fundamental inadequacy of our economic system to regulate its interactions with the environment. The policy implications of his analysis can only be sketched out at this time and this paper closes with an attempt to do so.

E2

VALUATION DISPARITIES AND ENVIRONMENTAL POLICIES*

Jack L. Knetsch
Simon Fraser University
Burnaby, British Columbia V5A 1S6

The empirical evidence collected over the past several years seriously contradicts the common assumption of equivalence between alternative economic measures of environmental losses on which many environmental policies are based. For example, the proportions of respondents in a random Ontario household survey who said they would be willing to sacrifice $100 per year to "maintain fish populations in the Haliburton and Muskoka regions" from adverse impacts of acid rain, varied from 82 per cent to only 46 per cent depending on which of the two available measures was used. Nearly twice as many people valued the loss at more than $100 on the basis of a willingness to forego this much of a "reduction in direct and indirect taxes and prices," than were willing to pay this same amount in higher prices and taxes.

The accepted measure of economic value is what people are willing to sacrifice: gains are assessed by how much individuals are willing to pay to attain them, losses by the minimum compensation necessary to leave individuals as well off as they would be without the change. While the definitions of gains and

* This research was in part supported by Fisheries and Oceans Canada and the Ontario Ministry of the Environment.

losses differ, in practice environmental assessments and policy prescriptions are commonly based on the empirical assertion that measures of willingness to pay and to accept compensation will yield equivalent valuations; that, "practically speaking, it does not appear to make much difference which definition is accepted" (Freeman, 1979, p.3).

The finding of the very large difference between the willingness to pay and the compensation demanded valuations of fish losses in the Ontario survey is typical of the results of other studies. Examples of the reported findings, including several involving environmental values, are summarized in Table 1. This evidence suggests that environmental losses will usually be greatly understated when assessed by the willingness to pay measure rather than the more appropriate compensation demanded measure.

Although the results from numerous surveys and other controlled tests have indicated that large differences in the values can usually be expected, these findings have had little or no discernible impact on environmental analyses or policies. Losses as well as gains continue to be assessed for policy and planning purposes on the basis of the payment measure. This hesitation to take the disparity evidence seriously may be encouraged by the pragmatic consideration that: "Generally speaking, willingness to pay is easier to estimate than required compensation" (Kneese, 1984, p. 15), but for whatever reasons there remains a strong

reluctance to change long standing conventional practice. The practical guide remains that: "The willingness-to-pay approach still holds: the true costs of unfavorable impacts are the total amount that people would be willing to pay to avoid them" (Stokey and Zeckhauser, 1978, p. 152).

Table 1. Summary of Past Tests of Disparity Between Willingness To Pay (WTP) and Willingness To Accept (WTA) Measures of Value.

Study	Asset or Good	WTP	WTA	Ratio
Hammack and Brown (1974)	Marshes	$247	$1044	4.2
Sinclair (1976)	Fishing	35	100	2.7
Banford, et al (1977)	Pier	43	120	2.8
	Postal service	22	93	4.2
Bishop and Heberlein (1979)*	Goose hunting	21	101	4.8
Brookshire, et al (1980)	Elk hunting	54	143	2.6
Knetsch and Sinden (1984)	Lottery	1.28	5.18	4.0
Heberlein and Bishop (1985)	Deer hunting (hypoth.)	31	513	16.5
	Deer hunting (real)	25	172	6.9
Brookshire/Coursey (1987)	Trees in Park	10.12	56.60	5.6

The contrast between the accumulating evidence of a systematic and large asymmetry between the value of gains and losses and the "business as usual" rule of current analysis practice and policy design, suggests at least two lines of further study. The first might usefully be directed to further tests of the disparity, using varied experimental and survey designs to better assure that past results are not artifacts of the study designs used and to determine the extent to which disparities persist over repeated valuations and occur with varied kinds of entitlements. The second line of study might explore policy and analysis implications of any disparities.

Tests of The Disparity

The conventional assertion of valuation equivalence is based on the assumption that people assess gains and losses by comparing the value of end states. That is, comparisons between how they feel with their present wealth, for example, and how they would feel with their present holdings less $10; or between their well-being with present entitlements with a bit more or a little less pollution. However, this is not an accurate description of how people value most changes. Instead of comparing alternative end states, people usually evaluate gains and losses in terms of changes from some reference position. And they value losses from this neutral point much more than they do gains to it (Kahneman and Tversky, 1979).

Earlier studies found large valuation disparities whether hypothetical survey questions or real money exchange experiments were used. The original findings of differences were not due to the hypothetical nature of the evaluations, as suggested by some (for example, Dwyer and Bowes, 1978). More recent research has provided further tests of the influence of transaction costs on the findings and on the persistence of the value differences over repeated valuations (Knetsch, Thaler and Kahneman, 1988). Again, the results were much the same.

Another more recent experiment has provided a still more severe test of the valuation disparity by allowing continuous bargaining between potential buyers of a good who have each been given a windfall gain of money and potential sellers who have been received either much smaller sums or no money. Previous research has shown that there is a strong tendency for people to spend or give up such unanticipated gains, or "house money" in gambler's parlance, much more easily than their "own" money (Thaler and Johnson, 1988). Consequently, buyers who have been given such sums might be expected to be willing to pay larger amounts to acquire a good than they otherwise would; and such a willingness to give up more money to acquire the good would lead to more equal valuations of buyers and sellers.

The experimental test was carried out in two steps. Participants were randomly divided into pairs, and one member of each pair was first given an asset that could be traded to the

other person at any price that they agreed upon. The redemption value of the asset to each participant was previously prescribed by the experimenter and was deliberately arranged so that an advantageous trade could be made that would result in one party obtaining a far greater "profit" than the other. The person receiving the larger payoff from the first induced value market then became a potential buyer in a second market, conducted under identical rules, for a real good that was initially given to the other person in each pairing.

The results again demonstrated that losing a good is valued more than gaining the identical entitlement. Even when potential gainers were provided an the added incentive of giving up nearly pure windfall gains to acquire a good, they demonstrated that they overwhelmingly valued the good less than the people who had the original entitlement (Thaler, Knetsch, and Kahneman 1988). The buyers were still systematically willing to pay less for these assets than sellers demanded for the objectively identical rights.

A variety of different experimental designs have now been used to test the equivalence assumption and the persistence of observed disparities (Knetsch, Thaler, and Kahneman, 1988). The evidence provided by the results indicates that, contrary to traditional assumptions and conventional practice: losses are valued far more than gains, the differences are pervasive and large, the disparities are not attributable to wealth effects, the dis-

parities are likely to persist over repeated valuations, and they are not the result of avoiding transaction costs or strategic behaviour.

Research on Implications of the Disparity

The evidence strongly suggests that the conventional presumption of valuation equivalence may be a poor description of actual behaviour and may well lead to misleading assessments, inappropriate policy decisions, and resource misallocation. This apparent dependence of valuations on entitlements raises some question about the general propriety of various common economic assertions which are based on the presumption of value equivalence. A substantial number of these involve the economic analyses of environmental problems and the design of environmental policies.

Measurement of Losses

The valuation disparity findings suggest that most economic assessments of environmental losses will be seriously understated and decisions may be biased because of this.

Although most environmental management and policy decisions are not based on comprehensive and explicit estimations of economic costs and benefits, an awareness and appreciation of the economic consequences of alternative actions usually plays a sig-

nificant role in formulating options and choosing among them. It is common, for example, to base choices on some notion of what people seem to be willing to pay to obtain or to keep some asset or entitlement, or to avoid some form of environmental degradation. However, if the contemplated change imposes losses on individuals, or if it involves an action that will reduce their loss, then this usual practice will almost certainly greatly understate the values involved. As a consequence, too many environmentally disruptive projects will be encouraged, too many harmful activities will be allowed, inadequate mitigation measures may be undertaken when environmental values are at risk, and compensation for losses may be inadequate.

Another frequently omitted and otherwise understated cost is the loss imposed on people due to the risk or uncertainty of the consequences of an action. For example, many of the physical impacts of waste disposal or damages due to pollutants are often unknown. And this uncertainty itself is a cost as people indicate a willingness to sacrifice other things to be free of it. These sacrifices are as much expressions of economic value as damages to buildings or reduced yields of crops.

To the extent that uncertainties are adverse changes imposed on people, these losses are then best measured by the minimum compensation necessary to leave people as well off as they are without the uncertainty -- the compensation demanded measure. An accounting of the sums people are willing to pay to be rid of the

risk would likely greatly underestimate these costs.

Similarly, environmental control standards will systematically be set at inappropriate levels if losses are assessed by the willingness to pay measure.

In an analogous way, liability for damages may be inappropriately assigned and thereby discourage fully justifiable levels of protection from environmental and other harms. The standard of reasonable care is often used as a guide for the efficient resolution of conflicts. If the expected damages from an action (that is, the probability of occurrence multiplied by the value of the loss if it occurs) exceed the cost of avoiding an accidental loss, a ruling of liability for damages will encourage cost justified precautions; if the cost of avoiding further injuries is greater than the expected loss, then the present standard of care is judged to be reasonable and the denial of damages will discourage precautions which are not cost justified. However, this criterion of when precautions are or are not justified is critically dependent on the measure of loss. More damaging activities and fewer preventative measures will be undertaken with the use of the willingness to pay measure of loss than would be the case with the usually more appropriate compensation measure.

The pervasiveness of valuation disparities may also alter the preference between mitigation measures and compensation as

alternative remedies to deal with environmental harms or losses. The conventional economic analysis suggests that, all other things equal, compensation will normally be the more efficient and preferred means to deal with losses. The advantage is assumed to be the lack of restrictions attached to a compensation payment, which permits recipients to use the funds for whatever good or service they value most. An equal sum spent on mitigation would restrict recipients only to the benefits of reducing the harm -- which may or may not be of much importance and value to the people affected.

The disparity findings suggest an alternative view of the relative merits of compensation and mitigation. Compensation may be viewed by people as two events: a loss associated with the harm, and a heavily discounted gain of a money payment. A mitigation measure, on the other hand, may well be treated as reducing the loss associated with the harm, and will consequently be regarded as being more important.

The strength of this intuition has been borne out by the results from some preliminary surveys indicating that affected parties may well value mitigation or replacement measures more highly than compensation payments, even when the sum of the payments exceeds the expenditure on the mitigation works or when the mitigation seems to serve little beneficial purpose. For example, slightly over half of student respondents preferred to have an accidently destroyed old textbook which had been used in an

earlier course replaced rather than receive the cash that they could then use for another currently needed text or for any other purchase. They expressed the same preference for replacement of a paperback novel which they had already read, even though this would appear to have less value to them than other things -- including a new novel -- they could buy with a compensation payment.

From 80 to 90 per cent of other respondents expressed a preference for spending money on reducing nuisances associated with a new waste disposal facility rather than paying compensation to people in the area, even when the payment was sufficient to make up for any loss in property values or was greater than the amount to be spent on the mitigating activities.

About 70 per cent of another group of survey respondents thought that a new business should spend a large sum of money on efforts that would only be partially effective in overcoming a relatively minor environmental problem, rather than accepting the business's offer to spend a like sum "on whatever use is decided on by local residents in a referendum."

These results are also consistent with findings of community preferences in dealing with waste disposal site selection (Zeiss, 1988). Compensation policies do not appear to carry the efficiency benefits often ascribed to them on the basis of valuation asymmetries.

The evidence that people value losses from a reference position much more than gains beyond it, may also have implications for a wide array of quota allocations and reallocations, issuing and termination of licenses, and treatment of people experiencing adverse impacts of changes.

The asymmetric valuation of gains and losses appears to be a major reason that people judge some actions as acceptable and fair and others as unacceptable and unfair (Kahneman, Knetsch, and Thaler, 1986). Changes or reallocations that are seen to impose a loss on one party for the benefit of another are very likely to be seen as unfair and therefore far less acceptable by a wide consensus of people that extends well beyond the individuals immediately involved. While the extent to which the views of a wider public should influence policies that have a larger impact on smaller groups is a continuing question, there seems to be surprisingly general agreement on the circumstances that make particular impositions of losses and conferring of gains more or less acceptable.

The asymmetric valuation of gains and losses suggests that policies might be more acceptable to the extent that they are seen, for example, as: undertaking more explicit and extensive measures to mitigate losses, combining offsetting gains with losses to reduce feelings of loss due to the changes, establishing a more visible link between current reductions and later

gains to the same individuals, breaking perceptions of gains of one group coming from losses imposed on another, and framing losses in terms of foregone gains or setting out changes that may be thought of as being less than permanent in nature. An example of the last of these is the usual lack of concern that typically accompanies loans of national art treasures as opposed to their sale to people planning to export them (Frey and Pommerehne, 1987).

Reference Points and Loss Measures

The valuation disparity results raise the important question of what people regard as their reference point in judging gains and losses. The reference position will, for example, determine whether people regard a change such as improving air quality as an improvement or as a mitigation of a past harm. That is, do people regard the present quality of air as the reference level, or is some notion of clean air their normal reference? The reference point actually used by people will in large part determine the most appropriate measure to use in each particular case.

A control program to reduce pollution, for example, is likely to be far more valuable, and more likely to be worth doing, if it is regarded by people as reducing a harm rather than an improvement. This greater value is due to people weighing reductions of losses more heavily than they do commensurate gains.

A common presumption is that the choice of measure is entirely dependent on existing legal entitlements: "the value of a resource ... will vary with the assignment of property rights" (Krutilla and Fisher, 1985, p. 36). It seems more likely that the choice of measure is more appropriately a matter of the reference point that people actually use (Knetsch, 1987).

Legal entitlements may or may not influence reference positions, but it is the reference point that likely determines the proper measure of the welfare change and the size of the gain or loss. An indication of this lack of determinateness of the legal regime was provided in a study of range laws in California (Ellickson, 1987). One half of a county operated under open range law and the other half under closed range. In spite of the opposite assignments of liability for any damages to crops done by cattle, and the fact that the laws were well known by local residents in both parts of the county, cattle owners were held responsible in all cases. The reference position seemed clearly to be consistent with crop damages caused by cattle being considered a loss despite the extant legal position.

Conclusions

In sum, the conventional assertion that values attached to gains and to commensurate losses are equivalent seems to be incorrect for at least a large class of cases. These are very

REFERENCES

Banford, Nancy, Jack L. Knetsch and Gary A. Mauser, (1979), "Feasibility Judgements and Alternative Measures of Benefits and Costs," Journal of Business Administration, 11, 25-35.

Bishop, R. C., and Thomas A. Heberlein, (1979), "Measuring Values of Extra-Market Goods: Are Indirect Measures Biased?", American Journal of Agricultural Economics, 61, 926-930.

Brookshire, David S., Alan Randall, and John R. Stoll, (1980), "Valuing Increments and Decrements in Natural Resource Service Flows," American Journal of Agricultural Economics, 62, 478-488.

Dwyer, John F., and Michael D. Bowes, (1978), "Concepts of Value for Marine Recreational Fishing," American Journal of Agricultural Economics, 60, 1008-1012.

Ellickson, Robert C., (1987), "A Critique of Economic and Sociological Theories of Social Control," Journal of Legal Studies, 16, 67-99.

Freeman, A. Myrick, (1979, The Benefits of Environmental Improvement, Washington, D.C., Resources For the Future.

Frey, Bruno S., and Werner W. Pommerehne, (1987), "International Trade in Art: Attitudes and Behaviour," Rivista Internaxionale di Scienze Economiche e Commerciali, 34, 465-486.

Hammack, J., and G. Brown, (1974), Waterfowl and Wetlands: Toward Bioeconomic Analysis, Baltimore, Md.: Johns Hopkins Press.

Heberlein, Thomas A., and Richard C. Bishop, (1985), "Assessing the Validity of Contingent Valuation: Three Field Experiments," Paper presented the the International Conference on Man's Role in Changing the Global Environment, Italy.

Kahneman, Daniel, Jack L. Knetsch and Richard Thaler, (1986), "Fairness as a Constraint on Profit-Seeking: Entitlements in the Market," The American Economic Review, 76, 728-41.

Kahneman, Daniel, and Amos Tversky, (1979), "Prospect Theory: An Analysis of Decision Under Risk," Econometrica, 47, 263-291.

Kahneman, Daniel, and Amos Tversky, (1988), "Loss Aversion," Working paper, University of California, Berkeley.

Kneese, Allen V., (1984), Measuring the Benefits of Clean Air And Water, Washington, D.C., Resources For the Future.

Knetsch, Jack L. (1987), "The Disparity Between Loss Evaluations and the Choice of Measure," Working paper, Simon Fraser University.

Knetsch, Jack L., and J. A. Sinden, (1984) "Willingness to Pay and Compensation Demanded: Experimental Evidence of an Unexpected Disparity in Measures of Value," Quarterly Journal of Economics, XCIX, 507-521.

Knetsch, Jack L., Richard H. Thaler and Daniel Kahneman, (1988), "Experimental Tests of the Endowment Effect and the Coase Theorem," Working paper, Simon Fraser University.

Krutilla, John V. and Anthony C. Fisher, (1985), The Economics of Natural Environments, 2nd ed., Washington, D.C., Resources For the Future.

Snclair, William F., (978), The Economic and Social Impact of Kemano II Hydroelectric Project on British Columbia's Fisheries Resources, Vancouver: Department of Fisheries and Oceans.

Stokey, Edith, and Richard Zeckhauser, (1978), A Primer for Policy Analysis, New York, Norton and Company.

Thaler, Richard H., and Eric J. Johnson, (1988), "The Mental Accounting of Prior Outcomes in Risky Choice," Working paper, Cornell University.

Thaler, Richard, Jack L. Knetsch, and Daniel Kahneman, (1988) "The Coase Theorem and Valuation Asymmetries," Working paper, Simon Fraser University.

Zeiss, Christopher, (1988), "Siting Waste Disposal Facilities in Host Communities: Impacts and Acceptance," Unpublished Ph.D Dissertation, University of British Columbia.

E3

THE PSYCHOSOCIAL IMPACTS OF EXPOSURE TO ENVIRONMENTAL CONTAMINANTS IN ONTARIO: A FEASIBILITY STUDY

S. Martin Taylor
Dept. of Geography
McMaster University

John Frank
Dept. of Preventive Medicine and Biostatistics
University of Toronto

Murray Haight
School of Urban and Regional Planning
University of Waterloo

David Streiner
Dept. of Psychiatry
McMaster University

Stephen Walter
Dept. of Clinical Epidemiology and Biostatistics
McMaster University

Norman White
Faculty of Health Sciences
McMaster University

Dennis Willms
Dept. of Clinical Epidemiology and Biostatistics
McMaster University

INTRODUCTION

Public concern in Ontario over the possible toxic effects of exposure to environmental contaminants is high in the wake of past highly publicized events elsewhere, for example, Love Canal, Three Mile Island, and Chernobyl. Local situations, such as the Upper Ottawa Street Landfill Site in Hamilton, reinforce concerns and give them more immediacy. Recent disclosures regarding PCB disposal sites, radon gas emissions and electro-magnetic radiation also contribute to uncertainty and anxiety over health risks. Equally, the prospect of the future location of new solid and liquid waste disposal sites compounds public fears and generates community reaction.

Research on the human health consequences of environmental contaminants has focussed primarily on possible physical effects (e.g. cancer outcomes). Increasing attention is now being given to psychosocial morbidity, in part as a result of research undertaken in the wake of such high profile events as the accident at Three Mile Island (e.g. Sorenson et al., 1987; Vyner, 1988).

Superficially, the link between exposure to contaminants and negative psychosocial outcomes (e.g. anxiety, depression, domestic and interpersonal problems) is self-evident. On closer examination, however, current knowledge based on past research is fragmentary, and a necessary starting point for future investigation is a critical appraisal of the existing literature. Recent reviews (Madisso, 1985; Michalenko and Lerner, 1987) provide a general description of the types of research attempted and the main findings reported but do not provide a critical appraisal of the evidence contained in previous studies.

This paper describes the development and application of a methodology for assessing the literature on the psychosocial impacts of environmental contaminants. The methodology was devised as part of a feasibility study for which the eventual end point is a protocol for research on the psychosocial impacts of environmental contaminants in Ontario. Although the intended purpose of the methodology is quite specific, the governing principles of critical appraisal on which it is based are quite general. It follows that the method has potential application to the assessment of research on a broad range of environmental health issues.

OVERVIEW OF THE METHODOLOGY

The methodology was designed with the following critical appraisal objectives in view:

> To assess the strength of the evidence for causal links between exposure to environmental contaminants and psychosocial impacts.

To develop a conceptual model of the process linking exposure to environmental contaminants and psychosocial impacts.

To assess the strengths and weaknesses of feasible research designs for the study of psychosocial impacts.

To evaluate existing instruments for measuring psychosocial impacts of exposure to environmental contaminants.

To assess analytical/statistical methods for estimating relationships between exposures and outcomes.

To evaluate approaches for determining the exposure characteristics of populations.

To identify population sub-groups particularly susceptible to psychosocial impacts.

To review the implications for public education of the psychosocial impacts of exposure to environmental contaminants.

The methodology divides into three stages: literature search, screening and appraisal. The first two are straightforward and require only brief comment. The appraisal procedure is more complex and needs fuller description and explanation.

Literature Search:

Increasingly, researchers have come to depend on computer-based bibliographic search methods. The scope has increased as the size and number of computerized bibliographic data bases has multiplied. In the present case ten different data bases were searched (BIOSIS, Enviroline, Environmental Bibliography, Medline, NTIS, Pollution Abstracts, Popline, Psyc Info, Sociological Abstracts, and Toxline).

The initial search strategy was to use combinations of generic keywords for both exposure (e.g. 'environment', 'toxic', 'pollution', 'waste', 'risk') and impacts (e.g. '(di)stress', 'psycho', 'socio', 'health', 'behaviour'). This global approach was ineffective and inefficient. It generated literally thousands of citations, many of which were irrelevant, and several key citations were missed.

A revised strategy involved searching each data base for "key" citations to determine salient keywords specific to that bibliography. These were then used for a second comprehensive search. This was far more productive, but still failed to

identify some important references uncovered by preliminary manual search methods.

This experience is not unusual for users of bibliographic data bases in situations where the target literature is quite diverse (i.e. in this case, a wide range of relevant environmental contaminants and psychosocial outcomes) and therefore spread across a wide range of journals and classified using an unstandardized set of keywords. Consultation with other researchers in the field confirmed similar difficulties in identifying relevant literature on this topic using computerized search methods.

The net result was that it was necessary to supplement the automated search procedures with conventional manual methods. This involved a systematic search of all issues of relevant journals back to 1980. The journal list was defined in two ways: first, any journal containing a previously identified relevant article was included; second, potentially relevant journals listed as "high impact" in the Science Citations Index were added.

Citations identified by this combination of automated and manual methods were entered into a bibliographic data base using Word Perfect 4.2 for efficient data storage and retrieval.

Literature Screening

The list of citations generated by the search inevitably included items of varying relevance for the study objectives. A screening form was developed to identify articles for full appraisal. The screening form included three classification criteria: type of effect (physical, psychosocial), type of exposure (environmental, occupational) and type of publication (original research, methodology, review, conceptual, book, discussion/commentary). All citations dealing with relationships between environmental exposures and psychosocial effects qualified for full appraisal.

LITERATURE ASSESSMENT

The literature on the psychosocial impacts of environmental contaminants is diverse and calls for an innovative appraisal methodology. A literature assessment form was developed to fulfill two purposes: to summarize the content of each paper; and to evaluate the strength of evidence with reference to standardized methodological criteria. The form was the product of extensive discussion among the research team. Draft versions were pretested and revised as appropriate. A user's manual was written to ensure consistency in application of the form by assessors.

Content Summary Criteria

Check lists were developed to summarize the content of articles under five headings: study design; health outcome; exposure classification; sample design; and analysis methods.

Study design is a very important consideration in assessing the strength of evidence. The epidemiologic literature provides detailed discussion of design architecture and its implications for causal inference. Designs for environmental epidemiology are typically one of three generic types: cohort, case-control and cross-sectional (Marsh and Caplan, 1986; Kasl, 1985). In addition, a variety of other designs are used (e.g. ecologic, time series and ethnographic).

A "diagnostic tree" was devised to determine the design used in each of the studies under review (Fig. 1). This consisted of a sequence of diagnostic questions. 'Yes'/'no' answers to each question defined a specific design type. For example, a design was classified as 'epidemiologic'/'individual level'/'cross-sectional' if the answers to the diagnostic questions were as follows:

> "Does the study review and quantitatively summarize 'primary data' studies? NO
>
> "Does the study attempt quantitative inferences about the risk of any health outcome associated with exposure to environmental hazards?" YES
>
> "Does the study analyze a risk/exposure relationship using human individuals as the unit of analysis?" YES
>
> "Are all exposures and health outcomes referent to the same point in time?" YES

The classification of health outcomes in the target literature is complex because of the wide range of physical and psychosocial effects reported. Although not the primary focus of the inquiry, it was essential to include physical effects because they are frequently reported in combination with psychosocial outcomes. Indeed, self-reported physical symptoms may in themselves represent psychosocial effects. A comprehensive checklist was devised to reflect current thinking about morbidity. Lists were written under five major categories: disease outcome (by body system and type); objectively measured dysfunction (physical, neuropsychological and psychological), illness stigmata (physical, emotional and cognitive complaints), illness behaviour (health concerns and help-seeking), and disability

(vocational/educational, activities of daily living, domestic and interpersonal, social and recreational).

Exposure definition is also complex. It is important to consider several aspects. Six classification categories were included in the appraisal form: experience, source, pathway, culprit, economic benefit and public familiarity. Several of these deserve brief comment.

It is important to document the nature of the exposure experience. The distinction is made between actual (past or present), future and perceived exposure, although these are not mutually exclusive. Psychosocial effects are frequently reported in situations where actual exposure either has never occurred or is in doubt. This is obviously the case where effects occur in advance of the presence of a contaminant (e.g. anxiety in anticipation of a future waste disposal site). Equally, effects are reported in response to perceived past or present exposure which may bear little relation to measures of actual contamination. Another important distinction is between acute (e.g. accident situations) and chronic (e.g. industrial emissions) exposure. The (supposed) source of contamination (e.g. landfill site, heavy industry, ambient conditions) is significant given the perceived risk attached to certain types of facility (e.g. nuclear power plants) and the heightened awareness and mistrust which may ensue. The presence or absence of a 'culprit' for contamination affects whether there is an identifiable target for the expression of public concern and may influence the types of coping responses in an impacted community. Risk perception and reported effects may be related to the economic benefit, if any, attached to the source of contamination. This is especially evident in single industry towns where the pollution source is the major employer and fundamental to the economic base of the community. The inclusion of familiarity reflects the importance of prior public knowledge of contaminants and their possible health consequences. Knowledge about local risks may arise in a variety of ways; for example, from media coverage of comparable situations elsewhere or from the activities of local environmental groups.

For sample design and analysis, the appraisal form included items to cover details of sample size, composition and representativeness, and the specific types of statistical or other analytical methods employed.

Assessment of Evidence Criteria

The second part of the appraisal form was designed to provide a systematic basis for evaluating the strength of evidence reported in each of the papers under review. While there exist general epidemiologic principles for an evaluation exercise of this sort (Frank et al., 1988; McMaster Univ., 1981), there was no "off the

shelf" instrument suited to the specific literature in view. Items were developed for inclusion in the appraisal form to address the following major issues: the measurement of exposure to contaminants; the measurement of health outcomes; control of extraneous/confounding variables; strength of association; evaluation of study results; global assessment of credibilty.

It follows from the earlier discussion on the nature of the exposure experience related to psychosocial effects that the identification and measurement of exposure is inherently problematic. Thorough documentatation of the type, intensity and duration of exposure is unlikely in most studies. Typically, effects are reported in response to an uncertain 'dose' of uncertain contaminants. The problem is compounded when perceived exposure is considered, given that this can occur in the absence of any actual contamination at all. These complications not withstanding, items were included in the appraisal form to determine how, if at all, exposure agents had been identified and measured. In the same context, items to determine the use and adequacy of control groups were developed. An item was also included to assess exposure to 'health alarms' in the community (e.g. public health warnings, media reports, etc.) recognizing the potential influence they could exert on public reaction and reported effects.

The assessment of outcomes was considered in terms of appropriateness and accuracy. Appropriateness is related to the biological/psychological and epidemiological plausibility of the outcomes reported with reference to the contaminants in question. This is typically a difficult assessment to make for psychosocial outcomes because of their complex and uncertain causation and the absence of specific links to particular exposures. In short, a wide range of outcomes are plausibly related to an equally wide range of exposures. An additional issue is the timing of the outcomes relative to the exposure taking account of any latency period that might be involved. The assessment of accuracy involves sensitivity (i.e. few false negatives), specificity (i.e. few false positives) and bias (e.g. self-reported effects). The frequent use of self-report measures of undetermined reliability and validity complicates the assessment of accuracy.
Confounding variables are factors related to both exposure and outcome which, if not controlled in the study design or analysis, may lead to false inference about an exposure-outcome relationship. From the standpoint of assessment, it is relevant to determine the use and characteristics of control groups and particularly their comparability to the exposed population. Specifically, it is important to determine the adequacy of matching and/or the methods used to adjust for possible confounders in the analysis. Here again, the complex and uncertain causation of psychosocial effects is problematic because it is difficult to compile a full list of potential confounders. It is reasonable to suppose that various

sociodemographic variables (age, gender, socioeconomic status) are relevant. It may be important to consider psychological factors as well (e.g. personality traits).

Strength of association corresponds to the change in risk of an outcome occurring after exposure to an imputed cause. Two questions arise in assessing relative risk, namely its clinical or practical significance and its statistical significance. Items were included in the appraisal form to assess both. These two aspects of significance are not necessarily coincident. A relative risk may be judged clinically significant though not statistically significant (e.g. small sample sizes may preclude statistical significance despite a relative risk of clinically significant proportions). Alternatively, a statistically significant result may have uncertain clinical significance (e.g. if the outcome in question has undetermined health consequences). A third consideration regarding strength of association is the demonstration of a dose-response relationship (i.e. risk increases monotonically with increased exposure) and an item was included to judge this. Where a relationship is present there is strong evidence of a true effect. On the other hand, its absence may be due to many factors and it is therefore not a definitive criterion. The frequent absence of precise exposure measures for reasons already described precludes the calculation of dose-response relationships in many studies.

The overall evaluation of reported results comes down to the question of whether the demonstrated exposure-effect link is true positive, false positive, true negative or false negative. All of the evaluation criteria previously described have to be taken into account to make this judgment. Three items were included in the appraisal form to judge the possibility of a false positve association, a false negative association and the consistency with other studies of the same exposure-effect relationship.
The last of these is made more difficult if the exposure and outcome in question are not well understood from previous research.

Three final items were included on the appraisal form to provide a global assessment based on all of the previous criteria. The first required a judgment as to whether the evidence supported an association for each exposure-outcome relationship examined. The second item determined if there were other factors which might cast doubt on the validity of the association (e.g. temporality, biological/psychological credibility, consistency with other studies). The last item called for a bottom line judgment on the credibility of the study.

APPLICATION OF THE METHODOLOGY

Results of the Literature Search and Screening

The combination of automated and manual literature search methods previously described resulted in the compilation of a bibliography containing 296 citations. These were classified according to the three major criteria (type of effect, type of exposure, and type of publication) on the screening form. Classification codes were included with each citation in the bibliography which was stored as a Word Perfect (secondary merge) file. Search and selection within this file allowed for the generation of subfiles defined by user-specified requirements (e.g. original research studies of relationships between environmental exposures and psychosocial effects.)

The frequency distribution of citations according to the screening criteria is summarized in Table 1. As intended by the choice of search strategy and keyword selection, most citations deal with psychosocial effects (263) and environmental exposures (192). 164 studies involve a combination of these two. Both physical and psychosocial effects are quite frequently examined within a single study (68 citations). An exposure-effect relationship was examined in 175 cases. In terms of type of publication, 'original research' is the most frequent category (160) followed by 'conceptual' (81) and 'discussion/commentary' (64).

The subset of studies for full appraisal was defined as those which examined a relationship between environmental exposure and psychosocial effects based on original research. 52 citations satisfied these criteria. These are the key papers for addressing the first of the objectives previously listed: to assess the strength of evidence for causal links between exposure to environmental contaminants and psychosocial impacts. The balance of the citations are the basis for a more general review of the literature in fulfillment of the other stated objectives.

Appraisal Procedure

Prior to the appraisal of the 52 papers, an inter-rater reliability test was conducted. This involved three team members making independent assessments of six papers using the appraisal form. The papers were selected to represent the range of topics in the full set of 52. The results showed a high degree of consistency among raters. The test did reveal some differences in interpretation of specific items on the form. These were reported to the full team and agreement was reached on standard interpretations.

At the time of writing the appraisal is nearing completion. The procedure has been for two team members to make independent

assessments of each paper. These are then checked for consistency. Differences in judgments on content summary items are in most instances resolved by checking the relevant factual details in the paper. Differences on the assessment of evidence items are resolved by discussion between the two asessors. Where this fails to achieve consensus, a third party from the research team is called on to reach a majority judgment. Consistent with the pretest findings, the differences have been relatively few and resolution has in almost all cases been achieved by consultation between the two original assessors.

Customized software has been developed for data entry from the appraisal form. This provides a VDT screen image of the form to facilitate data entry. The package is menu driven with facilities to modify and retrieve data and to copy user defined files. The modification procedure allows for the addition, deletion or correction of information. The retrieval facility is flexible allowing access by title, author, key words or particular appraisal items (e.g. study design, outcome, exposure). The software can create files for input to other programs (e.g. SPSSX) to facilitate further analysis (e.g. contingency analyses).

REFERENCES

Frank, J.W., Gibson, B. and Macpherson, M., 1988, Information needs in epidemiology: detecting the health effects of environmental chemical exposure, in **Information Needs: Environmental Risk Management**, Toronto: Institute of Environmental Studies.

Kasl, S.V., 1985, Environmental exposure and disease, in Baum, A. and Singer, J.E. (eds.), **Advances in Environmental Psychology vol. 5**, Hillsdale: Lawrence Erlbaum, 119-146.

Madisso, U., 1985, **A Synthesis of Social and Psychological Effects of Exposure to Hazardous Substances**, Research Report, Inland Waters Directorate (Ontario Division), Burlington, Ontario.

McMaster University, Department of Clinical Epidemiology and Biostatistics, 1981, How to read clinical journals IV: to determine etiology or causation, **Canadian Medical Association Journal**, 124, 985-990.

Marsh, G.M. and Caplan, R.J., 1986, The feasibility of conducting epidemiologic studies of populations residing near hazardous waste disposal sites, in Kopfler, F.C. and Craun, G.F., **Environmental Epidemiology**, New York: Lewis Publishers.

Michalenko, D. and Lerner, S., 1987, Negative stress as a health risk for people in situations involving environmental contaminants, unpublished paper, Department of Environment and Resource Studies, University of Waterloo, Waterloo, Ontario.

Sorenson, J., Soderstrom, J., Copenhaver, E., Carnes, S. and Bolin, B., 1987, **Impacts of Hazardous Technology: The Psycho-social Effects of Restarting TMI-1**, Albany: SUNY Press.

Vyner, H.M., 1988, **Invisible Trauma: The Psychosocial Effects of The Invisible Environmental Contaminants**, Lexington: D.C. Heath.

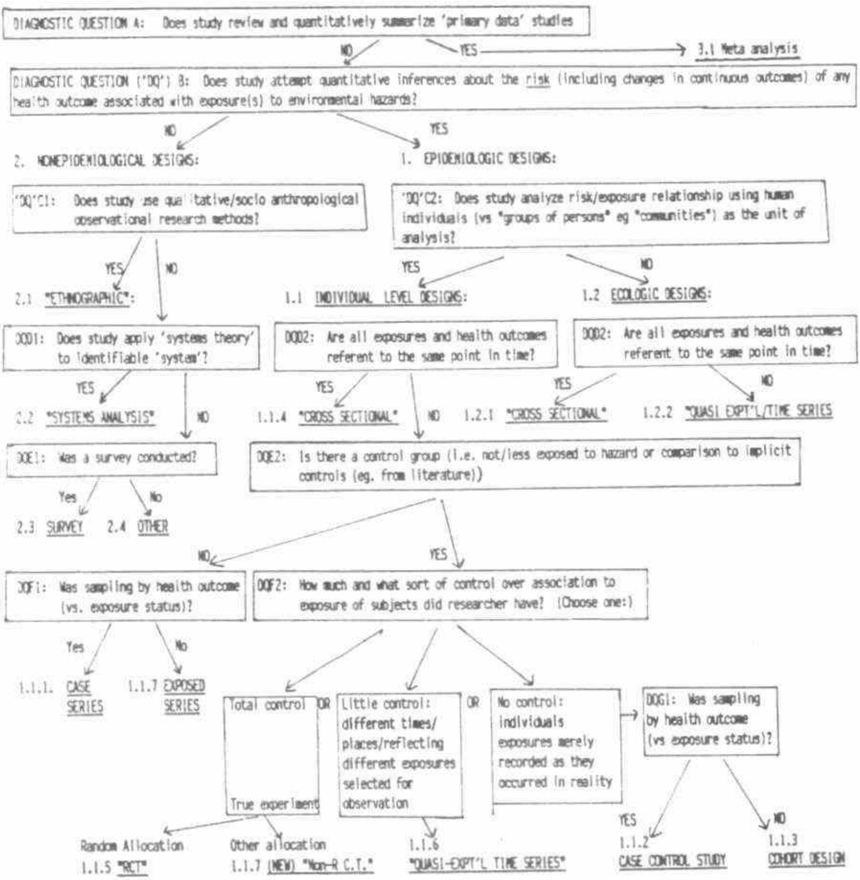
TABLE 1

FREQUENCY DISTRIBUTION OF CITATIONS

CATEGORY	**FREQUENCY**
HEALTH EFFECT	
Psychosocial	263
Physical	79
EXPOSURE	
Environmental	192
Occupational	82
EXPOSURE-EFFECT RELATIONSHIP ASSESSED	175
TYPE OF STUDY	
Original Research	160
Conceptual	81
Methodology	63
Review	53
Commentary	64
Book	22
TOTAL CITATIONS	**296**

Figure 1

STUDY DESIGN DIAGNOSTIC TREE



E4

ECONOMIC ASSESSMENTS OF MISA REGULATIONS FOR DIRECT INDUSTRIAL DISCHARGERS IN ONTARIO

By:

Orna E. Salamon, Jack A. Donnan

Socio-Economics Section
Policy and Planning Branch
Environment Ontario

November 1988

ABSTRACT

The Municipal-Industrial Strategy for Abatement (MISA) is a major initiative of the Ontario Ministry of the Environment, and is intended to achieve "virtual elimination of toxic contaminants in municipal and industrial discharges into waterways." Key elements of the program will be comprehensive monitoring and discharge limits regulations that will be applied to all municipal and industrial wastewater dischargers. An economic component of the MISA program is designed to assess the economic implications of the proposed regulations prior to their implementation. Economic profiles have been prepared for each of 9 industrial sectors whose direct discharges into provincial waterways will be regulated under the MISA program. Estimates of the costs of MISA monitoring regulations are being generated for each sector and the efficiency and distributional implications of these costs are being assessed. To the extent possible, cost-effectiveness of the proposed requirements are being examined. Preliminary results indicate that monitoring requirements alone will total approximately $3.5 million for Ontario Petroleum refineries and $8.9 million for 19 organic chemical manufacturing plants in the province over the 12-month period of the regulations.

1.0 INTRODUCTION

This paper presents an overview of the economic assessment program supporting the Ministry of the Environment's MISA initiative. The principles and scope of this program are integral to all MOE initiatives. The analytical work carried out to assess the economic and financial implications on direct industrial dischargers of the MISA monitoring and abatement regulations will be the focus of the present paper.

1.1 Overview of the MISA Program

The Municipal-Industrial Strategy for Abatement (MISA), was announced by the Ontario Ministry of the Environment in June 1986. MISA is intended to achieve the "virtual elimination of toxic contaminants in municipal and industrial discharges into waterways" (MOE[16] p.7). The MISA program will encompass over 200 mines and industrial establishments in Ontario which discharge their wastewaters directly into provincial waterways. In addition, over 400 municipal sewage treatment plants, which receive wastewaters from nearly 12,000 industrial plants will be subject to tighter controls under the MISA program.

As discussed in the "White Paper" (MOE[16]), the MISA program includes :

1. Establishing regulations which require each plant to monitor its effluent for a wide range of contaminants.

2. Development of regulations which will specify effluent limits which are based on "best available technology, economically achievable" (BATEA), or on water quality impacts, whichever is more stringent.

3. Implementation of enforcement activities to ensure that all

the specified monitoring and effluent limits are implemented according to program requirements.

4. Full public consultation, including the general public and interest groups, in developing the MISA program and regulations.

For the purposes of the MISA program, industrial establishments which are direct dischargers to provincial waterways are disaggregated into industrial sectors. Monitoring and effluent limits will be developed for the following sectors over the next three years. Additional industries may be defined as necessary.

- petroleum refining
- organic chemical manufacturing
- pulp and paper
- iron and steel
- metal mining and refining
- industrial minerals and manufacturing
- electric power generation
- inorganic chemicals
- metal castings

A list of the firms and plants included within the first two industrial sectors as of October 1, 1988 is found in Appendix A.

To achieve the fourth objective, public consultation, Joint Technical Committees have been established for each MISA industrial sector and for municipal sewage treatment plants. These Committees are comprised of provincial, federal and industry representatives who develop the actual regulations. The draft regulations and other components of the MISA program are also reviewed by the MISA Advisory Committee which is made up of representatives from public interest groups.

Monitoring requirements common to each of these sectors are specified in the "Effluent Monitoring - General" Regulation (MOE[14]). Included are sampling, analytical requirements, toxicity testing, flow measurement, recording and reporting protocols. This 'General Regulation' came into force on June 7, 1988 together with the first sector-specific regulation for the petroleum refining sector.

The general regulation will continue in force for each MISA sector while industry-specific regulations will be promulgated for each of the remaining sectors.

Once the results of detailed monitoring in each sector are available, effluent limit regulations can be specified.

Another component of MISA is a major Sewer Use Control Program which is aimed at contaminants being discharged through sewage treatment plants. The principles and elements which constitute the foundation of the proposed MISA Sewer Use Control Program are (Dillon[6]):

a) Control of indirect dischargers at the source.
b) Use of BATEA to set provincial discharge limits.
c) Application of more stringent discharge limits on a site-specific basis where necessary.
d) Require municipalities to act as the first line of enforcement.
e) Full public involvement.
f) Provincial legislative changes to give municipalities and the province the authority to obtain information and promulgate regulations.
g) Provincial auditing of municipal sewage treatment plant and industrial sewer user discharge data.
h) Provincial and municipal cost sharing schemes.

1.2 Plan of Paper

The purpose and components of the MISA socio-economic program are presented in Section 2. Some key economic principles which support such analytical work is also reviewed. Sections 3 and 4 then examine the economic assessments and evaluations that have been performed to-date, and preliminary results of this work are described. Section 5 looks at ongoing work.

2.0 SOCIO-ECONOMIC ANALYSES

The monitoring and abatement requirements that will result from the MISA program will likely be costly to achieve. Such expenditures could likely divert money and effort from other beneficial uses by government and private industry. Consequently, information on the costs of different means of achieving these requirements and their impacts on firms, industrial sectors, municipal governments, and provincial expenditure and staffing requirements is of vital interest to the Ministry of the Environment as well as industrial sectors subject to the MISA requirements.

A comprehensive economic assessment would require that information on the potential beneficial consequences of each of the regulations and other elements of the MISA program be developed and compared with the estimated costs. Benefits of the control of toxic contaminants include reduced risk to human health, protection of aquatic organisms and enhanced resource preservation.

However the MISA White Paper states that the technology-based effluent limits will be based on "best available technology, **economically achievable"**. Criteria must therefore be developed that define "economically achievable" and data must then be gathered that will permit assessment of the impacts of the costs of monitoring and abatement in each industrial sector and, where possible, on individual firms or plants. Where the costs of

compliance with the proposed regulations are found to be especially burdensome, information of the expected benefits of the requirements would help to choose what course of action might be taken.

2.1 MISA Economic Program

A program of economic studies has been initiated to generate the required information and to complement technical assessments and regulation development efforts. This program is outlined in a report entitled "Economic Information Needs and Assessments for Developing MISA Monitoring and Abatement Requirements" (MOE[9]).

The objectives of the economic program are:

a) to develop an economic database for those industrial sectors which will be subject to MISA monitoring and effluent limits regulations;

b) to develop estimates of the costs of proposed monitoring and effluent limits regulations for each industrial sector and for municipalities;

c) to determine the economic effects and consequences of these costs;

d) to develop criteria with which to define best available technology, economically achievable;

e) to design implementation programs that will achieve the MISA goals and objectives at least cost;

f) to contribute to the design of more effective policies and programs to control sewer uses by industrial dischargers; and

g) to provide information about the beneficial consequences of the various monitoring and abatement requirements including changes in the risk of certain health effects.

The economic program began with the preparation of industrial economic profiles for each sector. These profiles include physical and economic data, financial performance ratios, current trends, and forecasts of future market production and consumption trends. These profiles are discussed further in Section 3 of this report.

Following the production of economic profiles, studies are being carried out to estimate the costs of the proposed monitoring requirements for each sector and on individual firms and their plants, and to assess the economic and financial implications of these costs. These evaluations have aided Ministry personnel and the Joint Technical Committee in determining the most cost-effective methods of monitoring for selected contaminants. The cost of monitoring studies also identify those firms or plants which might be unduly affected by the regulatory requirements, and finally, judgements about the equity of the various program elements can be formulated.

By the end of the 12-month monitoring period, effluent limits regulations for each direct discharge sector will be developed. Abatement technologies to achieve MISA objectives will be identified and related costs estimated for each industrial sector. A key objective will be to find combinations of technologies that will achieve the MISA objectives at least-cost and to define criteria to help judge what is "economically achievable".

Estimates of the relevant costs are being prepared and financial impacts of MISA requirements are being evaluated for both direct and indirect dischargers. In addition, it is recognized that many of these industrial sectors will incur costs related to the control

of both direct and indirect discharges. Therefore the total, or net impacts on these industrial sectors are being carefully analyzed.

Table 1 below summarizes the economic program in relation to major MISA phases.

Table 1

Economic Components of MISA

MISA Phase	Economic Component
Pre-Regulation	* Industrial profiles - sector/firm/plant physical and economic characteristics - historical financial ratios - current and future market trends * Municipal Sewer Use Program Assessment (indirect industrial dischargers) - evaluate the proposed Sewer Use Control Programs with an emphasis on sewer surcharge programs and practices * Estimated cost of monitoring - estimates of incremental capital and operating costs - economic and financial implications for each sector and its firms and plants in domestic and international contexts **Help develop cost-effective regulations and identify potential impacts and problems.**
Monitoring Regulation	* Generic abatement technologies - determine costs of achieving various levels of controls - derive least cost programs to achieve specific effluent reductions

* Estimated cost of abatement

  - micro economic and sectoral impacts of various effluent limit scenarios
  - assessment of implications

* Actual costs of monitoring

  - assessment of implications of accumulated cost of MISA monitoring program

Effluent Limits Regulation	* Benefit and Risk Assessments - identify, quantify and value potential benefits and risk reductions for particularly contentious sectors - using economic models, determine the net benefits of MISA to Ontario, including the environmental protection industry

Provide input to other environmental policy initiatives.

2.2 Concept of "Economically Achievable"

Information and insights from the economic assessments will help to judge what levels of abatement and expenditure are "economically achievable" under BATEA. It is not a simple matter, however, to define "economically achievable". The term was first mentioned in the United States where the Clean Water Act,1977 uses the term, but does not provide a clear definition. Literature from the U.S. Environmental Protection Agency (USEPA), tends to define economically achievable by example.

When the USEPA instituted effluent limit regulations, it linked the average of the best existing performance of installed technologies in controlling conventional pollutants to, at minimum,

the best economically achievable performance of plants with shared characteristics. USEPA criteria involved in determining what technologies are best available and what the performance efficiency should be, included (MOE[16]):

- costs of applying the control technology
- age of the process equipment and facilities in place
- processes employed
- process changes available
- engineering or other technical aspects
- non water quality environmental considerations, such as air pollution, solid waste disposal, and energy consumption

The primary determinant of BAT, according to USEPA, is effluent reduction at a "reasonable" level of cost. In essence, the USEPA approach involves using average cost as an indicator of whether a technology or group of technologies is "economically achievable". That is, by examining how many industries use a particular technology, at what cost, and at what level of success in controlling the release of pollutants, it can be concluded that a particular technology is available, and economic in the opinion of industry.

In preparation for promulgating their effluent limit regulations, the USEPA commissioned a series of economic studies for each industrial sector. Using a representative report on the Pulp and Paper sector in the United States (USEPA[18]), the general scope of the USEPA economic analysis is be summarized in Table 2.

The USEPA material makes it clear that several issues must be clarified when defining BATEA.

Table 2

USEPA Economic Impact Analysis

* Cost of compliance on the sector and individual firms

  - using production information and data on treatment costs, calculate cost of compliance and the distribution of unit costs
  - make forecasts of industry capacity expansion to calculate costs of compliance by product sector
  - estimate costs of compliance both for capital costs and total annual operating costs

* Demand/Supply analysis for each market (product) sector

  - micro economic analysis
  - effects of increased costs on market factors such as prices and output

* Capital Availability

  - examine the ability of the industry to finance investments in new capacity both with and without pollution controls

* Closure Analysis

  - projected number (%) of closures
  - associated employment impacts

* Community impacts

  - indirect effects of any closures on employment and earnings

* Balance of Trade impacts

  - effect of increased prices on international competitiveness of products with significant amounts of exports and imports

First, technologies need to be evaluated and ranked on the basis of their ability to recover or reduce problematic pollutants. Thus, data on the removal efficiencies of different pollutants for each technology must be obtained. Removal efficiency is a

necessary, but not a sufficient, criterion for defining BAT. The greater the removal efficiency, the more likely that a technology will be "best available".

However, different technologies can have similar removal efficiencies. Another criterion must be introduced to choose among technologies with similar removal capabilities. The second criterion is cost-effectiveness. Best available technology can, therefore, be defined as the technology that achieves the greatest removal of particular pollutants at the lowest cost per unit removed. Consequently, information on the capital and operating costs of each technology or combination of technologies must be collected.

Studies have shown that different combinations of technologies can be identified that will achieve successively higher degrees of pollutant removal at least-cost until a maximum technically feasible limit is reached. The question then is what degree of removal (at least-cost), along the potential continuum, is "economically achievable" for a particular firm or industrial sector.

Once the cost and removal efficiency information is assembled into graphs known as least-cost abatement tables or cost functions, financial performance data for affected firms or industrial sectors can be compared to determine the relevant economic impacts and the behaviourial responses. Criteria must be defined to judge whether the costs are "economically achievable" or not.

As discussed earlier, the USEPA literature is vague on specific criteria that have been used in their regulatory programs. Indeed, it is likely that there is no single economic or financial criterion that will unequivocally show that a particular level of pollutant removal and cost is "economically achievable".

Nevertheless, these analyses will help ensure that the monitoring and abatement efforts are cost-effective. They serve to identify firms which will be most heavily burdened, and unproductive disputes about the costs and their implications can be minimized if not avoided entirely.

The Policy and Planning Branch of MOE is continuing to review the U.S. experience, and to evaluate the definitions of "economically achievable" in order to support the aim of MISA, which is to achieve the virtual elimination of toxics in the most cost-effective and equitable manner possible.

The next two sections deal with work done to-date, and presents results of economic analytical work.

3.0 INDUSTRY PROFILES

Industry profiles are intended to provide an economic database of the sectors and firms which will be subject to MISA and other environmental policy initiatives such as the proposed revisions to Ontario air quality requirements (Regulation 308) and waste management programs (Regulation 309). The Policy and Planning Branch of MOE developed a detailed Terms of Reference for industry profiles, which were to be carried out for each sector by consultants. Requirements specified in this Terms of Reference are described in Appendix B. This section details the methodology and goals of these profiles, as well as present the main findings and results of the assessments.

3.1 Methodology

The industrial profiles were intended to provide the Ministry with background information about each industry which could be used in the Joint Technical Committee deliberations. The consultants were told to limit their investigations to publicly available data. Suggested data sources included a literature search, company

financial reports, and Statistics Canada. Other sources considered were trade associations, banks, brokerage houses, trade journals, academic publications, and government documents and agencies.

The SIC, or standard industrial classification codes of some firms did not always fit neatly into either Statistics Canada data or into the MISA-specified industrial groupings. For example, Courtaulds Canada, part of the Organic Chemical Manufacturing sector, is classified as a textile manufacturer. Therefore, while Statistics Canada industry data used for organic chemicals were not directly related to this firm, it was assumed that trends and characteristics of the broadly defined Statistics Canada "chemical sector" would be applicable to firms outside the applicable SIC codes.

Table 3 lists the financial information considered necessary to assess the financial state of each sector and its constituent firms.

Table 3

Financial Indicators

Financial indicators calculated for each firm for the last five years:

- net income
- sales
- total expenses
- after - tax profits (losses)
- cash flow
- working capital
- total debt (long term and short term)
- capital expenditures
- total dividends (preferred and common)
- shareholders' equity (preferred plus common)

Financial ratios calculated for the <u>sector</u> and each <u>firm</u> for the last five years:

- working capital ratio (or current ratio)
- "quick" asset ratio
- debt to equity ratio
- interest coverage ratio
- net (after-tax) return on invested capital
- rate of return on total assets

In order to obtain a comprehensive picture of each industry, information about financial and economic performance internationally, nationally, for Ontario, and specifically for those Ontario plants subject to MISA was assembled.

In general, plant-specific data and information about non-public companies are not available. If firms are components of larger parent corporations, such as Esso Chemical to Imperial Oil, financial statements of the parent were supplemented with data on appropriate subdivisions of the larger firm. Firms have been invited to provide the Ministry with disaggregated, plant-specific financial data if they feel that consolidated statistics do not accurately reflect the condition of their operations.

Data tables were provided to the Ministry by the consultants on a PC Lotus 1-2-3 format to facilitate future updates and data manipulation. This feature is essential, since many of the original reports submitted by the consultants contained 1985 or 1986 data, which then had to be updated by Socio-Economic Section staff. Staff economists will continue to update the profiles in terms of any changes in market conditions and financial indicators. It should be noted that the profile for the first industrial sector, Petroleum Refining, has not been formally updated beyond 1985 statistics, and any discussion in the text of this paper refers to information found in recent company financial reports.

3.2 Sector Profiles

This section discusses the findings and results of two sector profiles. The three major areas of interest are highlighted: the definition of each sector, a discussion and assessment of market structure information including major products and competitive positions, and a review of financial and economic trends and forecasts.

The first sector, the Petroleum Refining industry, had its Monitoring Regulation promulgated June 7, 1988. The second, the Organic Chemical Manufacturing (OCM) sector had its Draft Monitoring Regulation issued for public review in mid-October. All the other industrial profiles which have been prepared are referenced at the end of the paper, and analytical work is currently underway for all of the remaining sectors.

3.2.1 Definition of the Industrial Sector

The first step in understanding an industrial sector is to define the sector in terms of the firms that comprise it and to identify the key products that are involved.

For some sectors, such as Petroleum Refining or Metal Mining, activities are clearly defined and fit well into traditional statistical data sources. However, for other MISA-defined industrial sectors, there is no clear definition of the sector. For example, firms in the "organic chemical manufacturing" sector range from large multinationals to small local specialty operations. The products of the firms vary widely. Some sectors are grouped together more for the sake of the MISA regulations than for any statistical logic.

Petroleum Refining Sector

Refineries process crude oil to make a wide range of products with the petroleum refining sector as one component of the vertically integrated multinational oil industry. Most major international oil companies are vertically integrated in that they operate in each level of the business, including crude oil production, crude oil transportation, refining, wholesale distribution and sales, and finally, retail sales.

The Canadian petroleum refining sector consists of 28 refineries which are owned by 12 different companies. There are seven refineries in Ontario which are owned by six companies: Esso Petroleum (Imperial Oil), Petro-Canada, Petrosar, Shell Canada Products, Suncor, and Texaco Canada. All seven of these refineries are subject to the MISA monitoring regulations.

As of 1985, Petro-Canada, Esso Petroleum and Shell Canada accounted for 56% of total Canadian petroleum refining capacity. The seven Ontario refineries accounted for 31% of total Canadian crude oil processing capacity (MOE[11]).

Within Ontario, five of the refineries are located in the Sarnia area, while two are in Oakville, near Toronto.

OCM Sector

Firms involved in the OCM industry may be disaggregated into subsectors which manufacture and/or process petrochemicals, those which make organic and specialty chemicals, and those which produce finished or end-use chemical products. Most organic chemical products are derived from crude oil and natural gas while a small proportion of products can be derived from animal fats, vegetable oils and other natural materials.

In Canada, about one third of available crude oil and natural gas quantities are used to produce all the petrochemical products that are used domestically or exported. These "feedstocks" are broken down (cracked) in petrochemical plants and then recombined (polymerized) to form new products such as plastics, paints, polyesters and fibres.

About 70 firms operate 150 chemical production plants in Canada. Of these, about 60 plants, or 40%, are located in Ontario. The next largest centres of activity are Quebec and Alberta. In Ontario, 19 of these plants, owned by 17 firms, are direct effluent dischargers and will be subject to MISA regulations.

3.2.2 Market Structure

An understanding of the market structure for each industrial sector aids in the assessment of the financial and economic impacts of regulatory initiatives such as MISA. Firms which sell primarily to highly competitive markets where there is a high potential for product substitution by consumers will find it difficult to pass on certain costs in the form of higher product prices. At the same time, firms that are owned by large foreign controlled multinationals may be able to absorb increased costs more easily than single plant, locally owned firms.

Other factors such as the nature of the products produced, the technologies employed, the number of people employed and the location of other plants are important in the development and assessment of cost-effective and equitable environmental protection policies.

Petroleum Refining Sector

Four companies account for just over 61% of the value of shipments of petroleum products in Canada, while eight firms account for 86% of the total value of shipments. In Ontario, the four largest

companies controlled 75% of the total refinery capacity during 1984 (MOE[11]).

Such statistics have led some authorities to characterize the oil industry as an oligopoly. In theory, this means that there are so few sellers in the relevant market that individual producers must take account of other firms' actions in making business decisions. In an oligopolistic situation, competition among major companies may be limited if firms possess market power as a result of this market structure and if demand for products is inelastic. Companies in an oligopolistic market would also be better able to pass cost increases along as higher product prices.

However, extensive investigations by Canadian government agencies found no evidence of past collusion or pricing agreements in the oil industry (WoodsGordon[20]). These studies also identified factors which limited to ability of Canadian oil companies to control market pricing. Moreover, the dismantling of the National Energy Program (NEP) in 1985 and the subsequent deregulation of oil prices in Canada means that offshore producers can now export petroleum products freely into Canada and Ontario, thus increasing competitive pressures on Ontario refineries.

Nearly 50% of Ontario's refinery production is transportation fuels (gasoline, diesel and aviation fuels). These fuels make up about 60% of the national petroleum output.

The value of Ontario shipments of petroleum products amounted to 6% of the provincial Gross Domestic Product (GDP) during 1985. The fact that the value of shipments has been rising steadily in the face of fluctuating and even declining production means that product prices (including taxes) have, on average, been rising steadily since 1977. Petroleum specialists have estimated that demand for gasoline, like cigarettes, is inelastic with respect to

price in the short run (eg. 6 months to one year). This means that a price increase will not engender a proportionate decrease in the amount of product consumed. From the industry's point of view, if demand for a product is price inelastic, prices can be increased without incurring substantial reductions in sales and revenues.

Over the longer run (eg. 2-5 years), demand may be more price elastic because consumers have opportunities to adjust their consumption patterns, find substitutes or produce more efficient fuel-using equipment. If these adjustments are made, and other conditions remain constant, firms could experience absolute reductions in consumption, revenues, and depending on cost conditions, a possible reduction in profits. It has been estimated that the long-term demand for light fuel oils is relatively price elastic.

OCM Sector

Firms within the petrochemical subsector tend to be large multinationals, the majority of which are foreign-owned. Two large firms in this sector, Polysar and Dow Canada, are Canadian-owned.

Canadian organic chemical firms sold over $5.0 billion worth of products in 1986, up over 2% from the previous year (MOE[12]). Of this amount, 62% were sold in Canada. The primary petrochemicals subsector produces benzene, ethylene and butadiene, among other products, which are in turn processed further to make intermediate petrochemicals that are used in other manufacturing processes. Consumer end-products of the organic chemical industry include plastics, carpeting, synthetic materials, furniture parts, and paints.

The organic chemical industry employed just over 17,000 people in Canada during 1986. While this is not large in terms of direct employment, the industry tends to generate substantial indirect

employment at subsequent stages of the manufacture of derivatives.

Firms in the Canadian and Ontario OCM sector can be generally described to be:

- net exporters of bulk petrochemicals and net importers of organic and specialty chemicals. Their major trading partner is the United States, which accounts for over 60% of Canada's exports and over 90% of major imported chemicals.
- price takers, with benchmark prices set internationally, primarily by American producers. These American producers in turn must take into account the rising influence of newer producers and consumers in the Pacific Rim, Middle East, and Europe. In the context of the world market, Canada is not yet large enough to influence trends. The Canadian OCM sector is, however, growing in importance.
- capital intensive, which tends to limit exit as well as entry into the industry. The large investment needed to capture fully economies of scale represents a barrier to firms who wish to enter the market in boom times, and to firms who wish to exit in poor times.

Canada has tried to protect its chemical industry with tariff and non-tariff barriers, with rates generally increasing as the product is upgraded. Such tariffs will be eliminated under the terms of the Canada-U.S. Free Trade Agreement.

Within Ontario, the primary and intermediate petrochemical producers tends to be oligopolistic (few sellers) and physically interdependent. This means that these firms tend to locate close together, as in Sarnia's "chemical valley", and sell products to each other. Figure 1 illustrates this feature.

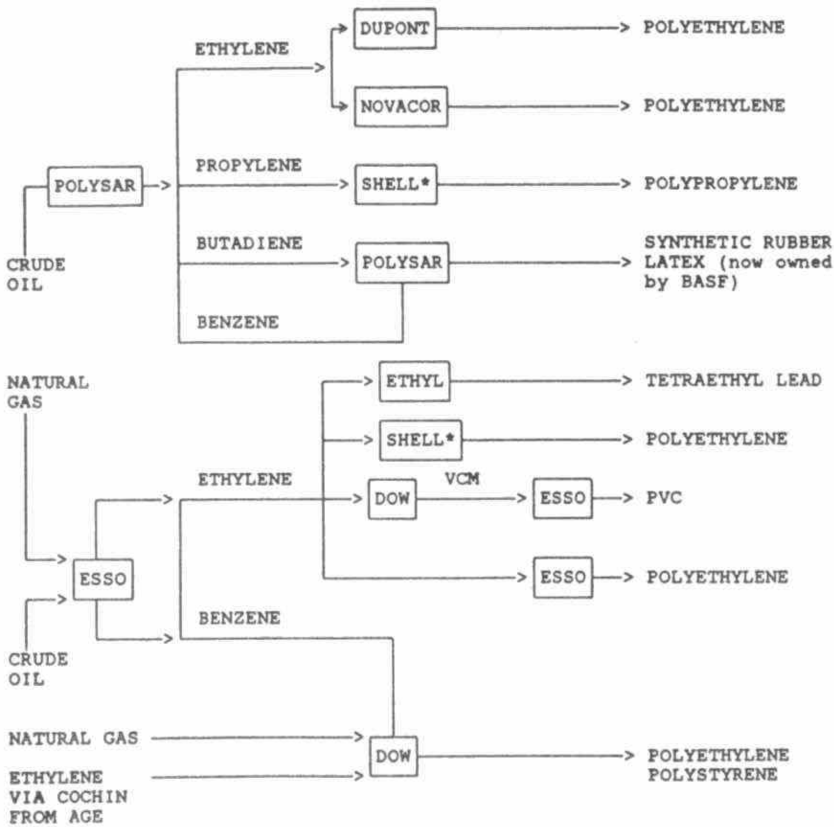
In a global context, primary and intermediate bulk chemicals are sold in competitive markets. The OCM sector is very dependent

Figure 1

SIMPLIFIED FLOWCHART OF

ONTARIO PETROCHEMICAL INDUSTRY INTERDEPENDENCE

IN SARNIA, ONTARIO



Source: MOE (12)

on the current business cycle, which is now at a peak. The 1987/88 demand for petrochemicals is currently growing, causing many firms to experience profits in their chemicals divisions. This represents a recovery from the recession of the early 1980's which caused depressed demand, falling prices, and losses by a number of firms.

3.2.3 Trends and Forecasts

It is not sufficient to view merely an annual "snapshot" of data of any given industry or firm. The current year may be an anomaly, or a transitional period. If these sectors were examined during the recessionary period, the assessments and predictions would be far different than at present. It is therefore important to get a sense of past trends and influences. Since the MISA and other regulatory programs come into force over a period of time, the sector profiles also attempted to look into the future and forecast accordingly.

Petroleum Refining Sector

The Canadian Petroleum industry has undergone significant "downsizing" in light of declining demand for refinery products. Remaining refineries tend to be larger and more efficient.

In 1985, the Canadian oil industry was deregulated and crude oil prices in Canada were determined by world prices. Shortly after the dismantling of the National Energy Program, world crude oil prices fell 58% between December 1985 and July 1986. The equivalent net effect on the retail price of gasoline would have been a 28% drop in price as of January 1986.

Figures 2a and 2b show that when crude oil prices and retail gasoline prices were falling, the proportion of the retail price going to refineries, dealers, and taxes increased. Lower crude oil prices should, therefore, enhance the financial performance of the

Figure 2a

RETAIL GASOLINE PRICE STRUCTURE
TORONTO REGION, JANUARY 1986
(PRICE = 50.7 CENTS PER LITRE)

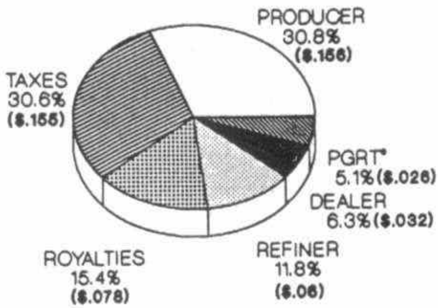
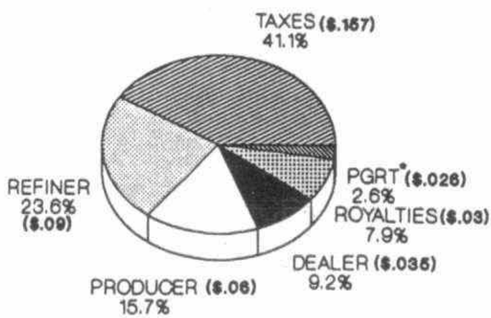


Figure 2b

RETAIL GASOLINE PRICE STRUCTURE
TORONTO REGION, APRIL 1986
(PRICE = 36.2 CENTS PER LITRE)



Source: MOE (11)

refining sector of the oil business since crude oil feedstock is the major operating cost in the refinery. In fact, falling crude oil prices resulted in higher returns to the refining component of the business (MOE[11], WoodsGordon[20]).

Figures 3 and 4 show comparative standings for five oil companies in Ontario for two selected financial indicators. After-tax profit, or net income, is the surplus remaining after all current expenses, interest, charges, and taxes are paid. This is a measure of the long term financial health of a company and an industry. Internal cash flow is defined as net income plus depreciation and is an indication of the ability to pay current expenses, declare dividends and finance expansion. A company which shows little or no after-tax profit can, for a short time, still meet its debts and obligations if cash flow from other sources is adequate. The larger the cash flow, the better.

Figure 3 shows that after-tax profits, or net income, have been increasing. Company annual reports further indicate that 1987 is a boom year, with many firms recording profits at much higher levels than in previous years. Figure 4 indicates that the cash flows of these firms continue to be positive.

Slow growth in product demand has prompted the contraction of refinery capacity and employment in recent years by means of closures and "rationalization" of facilities. Therefore, despite the healthy financial results recorded in 1987, long term growth is expected to be modest for the petroleum refining sector. Large capital investments have been made at Ontario refineries to keep these facilities competitive. There also continues to be uncertainty about the future in terms of oil prices and competitive pressures (MOE[11]).

Figure 3

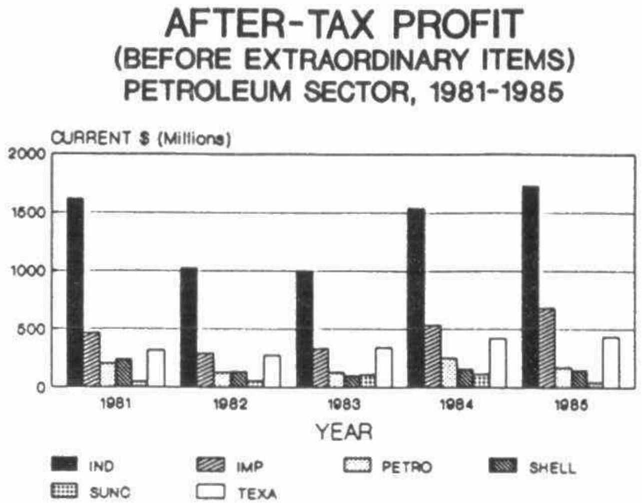
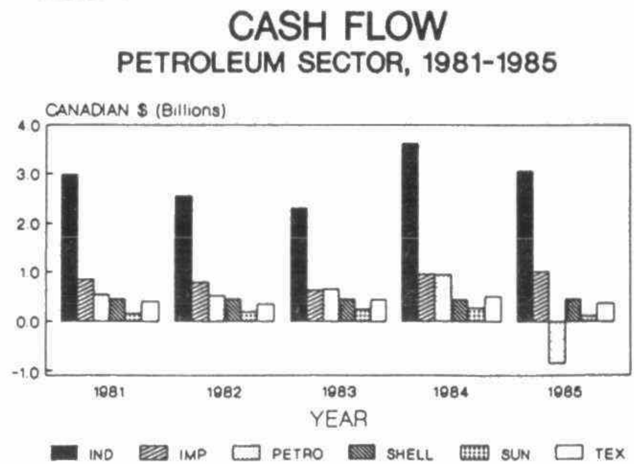


Figure 4



Source: MOE (11)

OCM Sector

Canadian producers experienced profits during the late 1970's due to positive economic growth and government initiatives such as the National Energy Program, which held the price of domestic oil and gas feedstocks below world prices. When Canadian oil prices were finally allowed to match world oil prices in the 1980's, the latter began to soften and fall. Feedstock costs for chemical producers were pushed up in the face of continued slack demand for their output. At the same time, producers carried the high capital costs of earlier expansions.

Currently, OCM sector companies are planning expansions and are experiencing record profits. For example, Polysar has recently restarted a mothballed styrene plant in Sarnia because of the low supply and rising demand for styrene, which is a building block in the manufacture of plastics and synthetic rubber. Polysar expects the styrene plant to add at least $18 million to company petrochemical earnings (MOE[12]).

A review of company performance statistics available for those firms whose plants are subject to MISA requirements reveals little homogeneity and large variation. In addition to the problem of having at best aggregated data, the financial performance indicators of the MISA designated OCM companies do not necessarily represent the organic chemical industry because some of the firms in the MISA sector make and sell products in a different industrial sector.

Figure 5 shows after-tax profit (net income) trends for selected OCM firms that are subject to MISA monitoring regulations. There has been a strong recovery in 1987, with most companies returning to or exceeding pre-recession profit levels. It can be seen in Figure 6 that most companies are showing steady improvement in their cash flow positions.

Figure 5

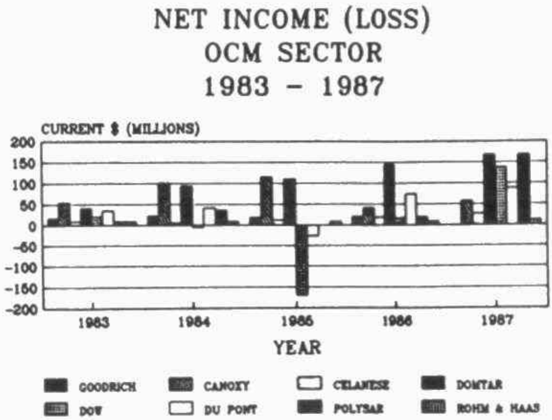
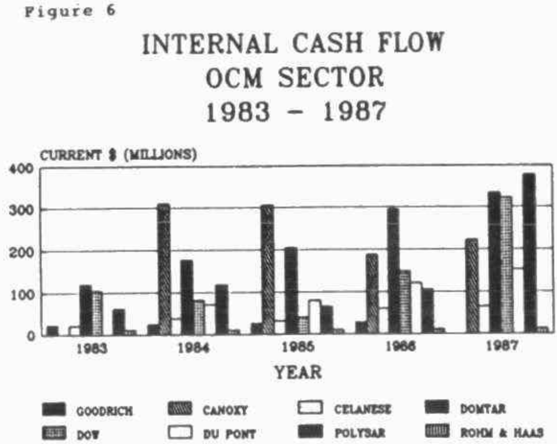


Figure 6



Source: MOE (12)

It is expected that rising demand for chemical products, combined with relatively lower feedstock prices, tight capacity in the petrochemical sector, and a weak Canadian dollar in relation to U.S. currency will continue to boost Canadian and, in particular, Ontario's organic chemical manufacturing sector performance statistics.

A review of company annual reports indicates that their chemicals divisions are profitable and expanding capacity. For example, the B.F.Goodrich plant in Ontario subject to the MISA monitoring requirements produces PVC (polyvinyl chloride) plastics. Its parent company, B.F.Goodrich, has a separate PVC and Intermediates Division which had sales revenues of $866 million in 1985 growing to $1.1 billion in 1987. Operating income for this division grew from a loss of $185 million in 1985 to a profit of $144 million in 1987. Total U.S. demand for PVC grew 7.3% in 1987. In fact, because of the high demand for PVC as a substitute for plastic and other non-plastic materials, many producers, including B.F.Goodrich, were unable to maintain adequate supply (BFG Annual Report 1987 in MOE[12]). Other firms in this MISA sector involved in the production of PVC are expected to do well.

The Canada-U.S. Free Trade Agreement will likely benefit the petrochemical sector because these producers export most of their output to U.S. customers. The organic and specialty chemical sector, which is a net importer, will probably benefit through the elimination of Canadian tariffs on U.S. imports, but could face greater competition from other sellers seeking to expand their markets. At this time, the implications of the Free Trade Agreement on individual plants is unknown.

Section 4.2 discusses the impacts of the estimated MISA monitoring costs on the OCM sector firms

4.0 ESTIMATED COST OF MONITORING

The monitoring requirements are the first step towards abatement regulations under the MISA program. The monitoring regulations will be in effect for a 12-month period for each industrial sector. Data from the specified monitoring activities will be used in the development of specific limits regulations.

The economic assessments present estimates of the incremental costs associated with the sector monitoring regulation. Impacts of these costs on certain financial indicators of the sector, and firms and plants within the sector, are also examined.

Section 4.1 outlines the methodology of these economic studies, and discusses the technical background for these estimates.

4.1 Methodology

The monitoring requirements translate into 6 monitoring functions or activities which each eligible plant must carry out. These monitoring functions include sampling (including transportation to laboratory facilities), characterization analyses, routine analyses, toxicity testing, flow measurement and reporting. Capital and operating costs are estimated for each of these activities as they apply at each plant.

Normally, operating costs are expressed as recurring annual expenses. However, the MISA monitoring regulations are in force for only a 12-month period so that all operating and capital costs will be incurred during that period.

Capital costs include costs incurred for equipment and installations which can be used longer than the one-year tenure of the regulation. These capital items would normally be depreciated over a period of several years. Consequently, only a portion of the capital expenditure would be counted as an expense for tax

purposed during the 12-month period of the regulation. Current depreciation rules permit a 3-year write-off for pollution control-related items at a rate of 25%, 50%, and 25%.

However, when assessing the impacts of the monitoring costs on plant and company financial performance, total incremental capital costs, rather than the depreciated values, were used in order to provide a conservative, maximum impact scenario.

Steps involved in cost estimation include the determination of what activities and resource inputs are required to implement each monitoring function, and the stated use of simplifying assumptions where necessary.

Cost estimates are based on specifications in the sector-specific monitoring regulations.

Single-valued or point cost estimates for monitoring activities are presented, but should be treated with some caution because:
- inputs required for different types of monitoring functions are often uncertain; and
- there is some flexibility as to how individual plants might actually implement some of the monitoring requirements.

The monitoring regulations for each sector are not identical. The Petroleum Refining sector has a common set of contaminants that each refinery must test for at the same frequency. This was done because refineries are fairly homogeneous production plants. Because the Organic Chemical Manufacturing (OCM) sector plants vary widely in the processes they use and the pollutants they discharge, plant and pipe-specific (ie. final discharge point) monitoring requirements are specified. This approach is potentially cost-effective because each plant in the OCM sector will only have to test for pollutants that are actually found in their particular

wastes.

Ranges of costs for some monitoring functions were included in the analyses where possible. Ranges in costs are due to uncertainties about capital costs and about the prices that will have to be paid for the analytical tests.

The MISA monitoring program is directed at all potential point sources of pollution entering surface watercourses, including treated or untreated process effluent, cooling water, stormwater runoff, emergency overflows, waste disposal site drainage, and combinations of the above. In order to estimate the costs of monitoring these final discharge points, it is important to understand what they mean.

Process effluent, with or without treatment, are the primary concern of the MISA program since they contain the highest concentrations and loadings of contaminants. The monitoring strategies are most comprehensive and rigorous for these waste streams. **Cooling water** is used to cool industrial process units and can be contaminated by leaks. In addition, chemicals are added to control slime growths and prevent corrosion. **Stormwater runoff** following rainfall or snowmelt events can carry contaminants from processing or storage areas. Storm drainage channels are often the route for leaks and spills to gain access to surface waters.

Waste disposal site drainage exists on-site in some industries that treat or dispose of solid waste on their own property. **Emergency overflow** routes often exist for untreated or partially treated wastewater. These are used only when treatment processes or equipment breaks down. **Combined effluent** are streams that are mixed with process effluent and possibly other wastewaters.

Finally **intake water** locations are points where water is drawn into the system. Intake water is <u>not</u> required to be sampled in the MISA program. Contaminants can be found in intake water as a result of polluted sediments from historical releases, upstream contamination, and recirculation of discharges from the plant site.

Figure 7 illustrates these different types of effluent streams for a typical industrial plant site.

The General Effluent Monitoring Regulation specifies requirements for the six major monitoring activities, which each wastewater discharger must implement to various degrees and levels of effort.

4.2 Estimated Costs of Monitoring and Their Implications

As noted earlier, two of the nine MISA designated industrial sectors have their sector-specific monitoring regulations issued at the time of writing. Accordingly, monitoring cost estimates and impacts for these two sectors have been completed thus far.

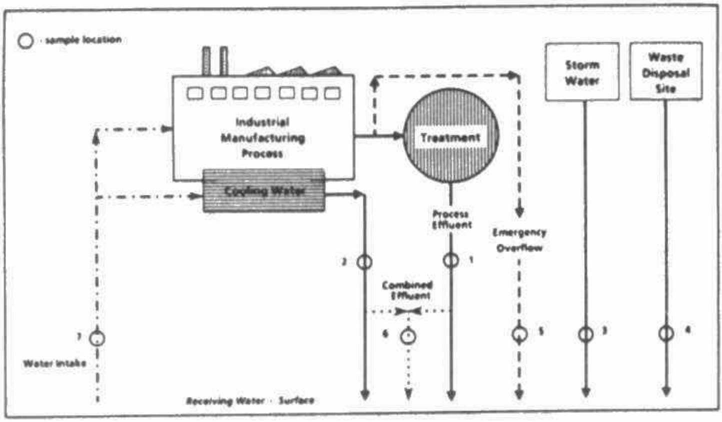
<u>Petroleum Refining Sector</u>

The total incremental capital and operating costs that could be incurred to comply with the monitoring regulations for this sector amount to $3.5 million with a range of $3.0 million to $4.3 million (MOE[8]).

The point estimate of the total capital cost is $1.6 million. Because of the uncertainties associated with these estimates, the actual total capital expenditures could vary by +/-30% or between $1 million and $2 million. Spokesmen for the refineries have emphasized that they intend to install automatic samplers and flow measurement facilities at virtually all of their sampling points and intake water locations in order to achieve the accuracy requirements of the regulations and to reduce long term, recurring labour costs that are associated with other methods of sampling and

Figure 7

Typical Industrial Plant Site Monitoring Locations



Source: MOE (14)

flow measurement.

The total operating costs for all monitoring activities, including contingencies, could amount to over $1.9 million. Oil firms indicate that these estimates could vary by +/- 15% or $1.6 million to $2.2 million.

The oil companies intend to spend more than what may be strictly required to comply with the monitoring regulations. If production efficiencies are not realized from these monitoring expenditures, then the extra costs will serve only to reduce profit and return on investment to refining assets.

There are no published disaggregated financial or production data on Ontario refineries. There are, however, statistics on the petroleum products segments for each company, except Petrosar. The financial data utilized for the five other firms are a consolidation of each company's petroleum product operations across Canada, not just the Ontario facilities.

The monitoring capital cost estimate for each refinery was computed as the percent of the lowest annual capital expenditure between 1981 and 1985. This quotient indicates how much of the firm's petroleum product segment capital budget would have been required for monitoring in that year.

Another measure of financial impact is the percentage by which the extra operating costs would reduce each company's after-tax profits (or increase losses) for the petroleum products segment of the company's business. The monitoring cost estimates were compared with the after-tax net earnings (net profits) for the segments over five years (1981 -1985) and against the lowest positive after-tax profit achieved during this same period.

Table 4 summarizes these comparisons. The results show that the point estimates of monitoring cost estimates account for less than 1% of total capital expenditures and net-earnings for four firms. Although small in comparison to the consolidated earnings of these multinational corporations, these extra costs can nevertheless have a significant effect on a segment of the firm's business and the plant to which the costs are assigned.

The cost estimates are largest in relation to the capital expenditures and after-tax earnings of Suncor, which suffered losses in recent years. Texaco Canada also incurred significant losses in 1983 and 1984. Monitoring costs would have increased these losses by about 1%.

The impacts of both capital and operating costs on a firm are mitigated by the tax system. Because all or a part of these costs can be deducted from taxable profits, the federal and provincial governments will share some of the costs in terms of reduced tax revenue.

Profit levels for the industry have been improving, with 1987 being a particularly profitable year. It can be concluded therefore, that, if the petroleum companies perform as well (or no more poorly) as they did over the past 5-6 years, the incremental costs resulting from the MISA monitoring requirements will not significantly impact the financial performance of the firms within the Petroleum Refining sector.

OCM Sector

The incremental capital costs of complying with the monitoring regulations for this sector are estimated to be about $2.2 million. These costs are subject to varying degrees of uncertainty, and representatives of the firms who provided these estimates indicate that this uncertainty could vary from +/- 5% to +/- 25%. Using an

Table 4

FINANCIAL IMPACTS OF ESTIMATED MONITORING COSTS ON THE CONSOLIDATED PETROLEUM PRODUCTS SEGMENT OF PETROLEUM COMPANIES						
			After-Tax Earnings (Loss) between 1981 and 1985		Total Operating Costs (with Contingencies) as a % of After-Tax Earnings (Loss)	
Company	Lowest Annual Capital Expenditure since 1981 for Petroleum Products Segments ($ Millions)	Point Estimate Capital Expenditure for Monitoring as a % of Total Capital Expenditure (%)	Total Earnings for 5 Years ($ Million)	Lowest Positive Earnings during the period ($ Million)	Total for 5 years (%)	Lowest Positive Earnings (%)
Esso	129 (1984)	0.30	776	61 (1983)	0.04	0.5
Petro-Canada	80 (1981)	0.16	1,033	88 (1982)	0.06	0.7
Shell Canada	40 (1985)	0.74	349	23 (1983)	0.08	1.4
Suncor	28 (1985)	1.86	64	1 (1984)	0.5	32.9
Texaco Canada*	59 (1983)	0.06	(25)	39 (1985)	(1.0)	0.6

* Capital expenditure and earnings data only available for 1983, 1984 and 1985

Source: MOE (8)

average uncertainty measure of +/- 15%, the total capital costs of the regulation requirements could range from $1.9 million to $2.5 million (MOE[15]).

The point estimate of the incremental operating costs of compliance is $6.7 million. These expenses will also be incurred over the 12-month period of the monitoring regulation.

The estimated total incremental capital and operating costs based on the monitoring functions in the OCM effluent-specific schedules for the nineteen plants in this sector are:

Sampling	$2.2 million
Characterization	$0.6 million
Routine Monitoring	$4.4 million
Toxicity Testing	$0.3 million
Flow Measurement	$0.9 million
Reporting	$0.5 million
TOTAL	$8.9 million

In order to illustrate the cost-effectiveness of the monitoring requirements, estimates of the routine analyses costs under an alternative set of assumptions were developed. As noted, the OCM sector involves plant and stream-specific requirements. If, however, OCM firms were required to adhere to a single, across-the-board set of monitoring requirements as does the Petroleum sector, the costs of monitoring would be vastly different.

This "stringent" scenario resulted in a point-estimate of routine analyses costs totalling $16.5 million, versus the $4.4 million under the OCM regulation requirements. This difference of $12.2 million represents a cost saving for the OCM sector, and is a measure of the cost-effectiveness of the pipe-specific approach used in this sector. The Ministry has been cognizant of the potential financial demands of the MISA requirements, and has incorporated such considerations in the development of the monitoring regulations without a significant loss of technical

data.

The impact of the monitoring costs of MISA on the Canadian OCM sector as a whole will likely be negligible. The estimated total capital cost of monitoring, $2.2 million, represents only 0.4% of the average annual capital expenditures recorded for the Canadian firms in this sector by the Canadian Chemical Producers' Association (CCPA) between 1982 and 1986 (MOE[15]). For the lowest annual level of capital expenditures during that period, the point-estimate for monitoring would be still under 1% of the average annual capital expenditure levels.

Employment impacts would be neutral to slightly positive, since the monitoring requirements might stimulate job opportunities for personnel to collect and analyze samples. Further employment opportunities will likely be generated in the form of consultants, analytical laboratories, and equipment manufactures.

The total estimated incremental costs of monitoring would reduce average (1982 - 1986) total pre-tax profits of the OCM sector about 5.8% (MOE[15]).

Given this small effect, monitoring costs are not expected to adversely affect the international competitiveness of the firms in the OCM sector.

Demand, sales, and earnings for the organic chemical industry are currently buoyant. Firms are planning to increase capacity to take advantage of relatively lower feedstock prices and rising demand for chemical products. Monitoring costs will, therefore, have a much smaller impact over the next 12 to 24 months than they would if they have been incurred in previous years.

Because plant-specific data are not generally available, the financial effects of monitoring must be assessed against consolidated company data. It is assumed that all of the firms in this sector operate in a competitive market and will not be able to pass cost increases on as higher prices. This assumption may be overly conservative for some firms which produce specialty chemicals and which have enjoyed tariff protection. Costs incurred over the 12-month monitoring period will therefore be reflected in reduced after-tax profits.

Table 5 shows how each plant's monitoring costs compare with capital expenditure and net profit trends for each company.

Estimated capital costs of monitoring represent less than 1% of company average annual capital expenditures. Rohm and Haas is an exception, with the capital costs of monitoring representing 3.3% of average annual capital expenditures.

The impact on average after-tax profit is also relatively low, with representative percentages of operating costs of monitoring ranging from 0.1% to 2.9%.

All the firms for which data are available have sufficiently large working capital balances to cover the monitoring costs. Firms which do not have sufficient working capital may need to seek external financing.

It can be concluded, therefore, that the imposition of monitoring costs will not pose an undue financial or economic burden on those firms within the OCM sector for which financial data were available.

Financial Impact of
Monitoring Costs - OCM Sector

Company/Plant	Capital Expenditures			After-Tax Earnings		
	Average 1983-1987 ($ Millions)	% Represented by Point Estimate Capital Cost of Monitoring		Average 1983-1987 ($ Millions)	% Represented by Point Estimate Capital Cost of Monitoring	
		Average	Lowest		Average	Lowest
B.F. Goodrich Canada Inc.	19.7	Ø	Ø	19.7	0.6	0.7
BTL Industries Inc.	N/A			N/A		
Borg-Warner (Canada) Limited	N/A			N/A		
CanadianOxy Chemicals Ltd.	130.0	0.02	0.1	68.1	0.1	0.2
Celanese Canada Inc.	22.7	0.3	0.5	8.2	2.5	(3.7)
Cornwall Chemicals Limited	*			*		
Courtaulds Fibres Canada (formerly Courtaulds North America Inc.)	*			*		
Courtaulds Films (formerly BCL Canada Inc.)	*			*		
Domtar Inc.	298.6	0.02	0.1	110.1	0.2	0.5
Dow Chemical Canada Inc.	81.0	0.7	1.0	0.4	**	(1.0)
(DuPont Canada Inc. - Corunna)						
(DuPont Canada Inc. - Kingston)	60.0	0.4	1.1	42.7	1.8	(2.9)
(DuPont Canada Inc. - Maitland)						
Esso Chemical Canada (Imperial Oil)	928.0	.03	.04	497.6	0.1	0.1
Chemicals Division	41.4	0.6	0.1	13.2	2.6	(3.4)
Ethyl Canada Inc. (Parent Company)	110.0	Ø	Ø	145.2	0.3	0.4
Chemicals Division	65.8	Ø	Ø	162.9	0.3	0.4
Novacor Chemicals Ltd.	263.1	0.01	0.02	87.1	0.1	(0.1)
Polysar Limited	217.8	0.3	0.3	46.2	2.9	**
Rohm and Haas Canada Inc.	1.9	3.3	4.7	9.4	1.3	1.4
Uniroyal Chemical Ltd.	N/A			N/A		

N/A No data available
* Insufficient data available
** Greater than 100%

Source: MOE (15)

4.2.1 Comparison of the Petroleum and OCM Sectors

Table 6 presents a comparison of the costs by monitoring function for each of the two sectors discussed in this paper.

Table 6
Comparison of Total Costs by Monitoring Function
($000's)

	Organic Chemicals		Petroleum Refining	
Sampling	$ 2,248	(25.1%)	$ 792	(22.6%)
Characterization	607	(6.8%)	19	(0.5%)
Routine	4,379	(48.9%)	1,289	(36.7%)
Toxicity	312	(3.5%)	74	(2.1%)
Flow Measurement	897	(10.0%)	770	(21.9%)
Reporting	504	(5.6%)	567	(16.1%)
TOTAL	$ 8,947		$ 3,511	

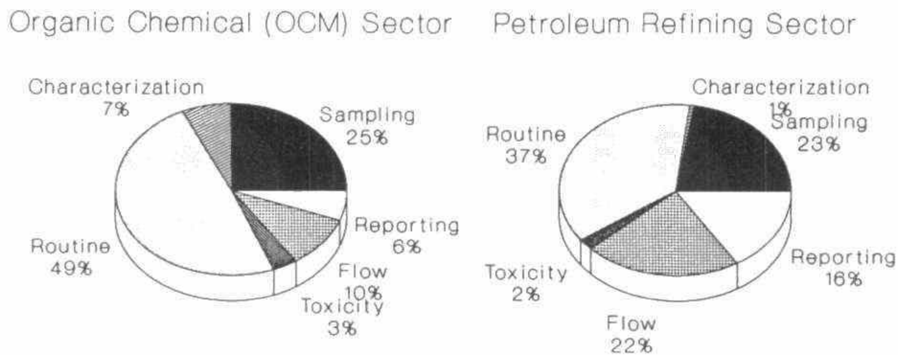
Figure 8 illustrates the different distribution of these costs among the monitoring functions in a pie chart format.

It is evident that routine analyses are the single highest cost component of monitoring for both sectors. It represents nearly half of the estimated costs for the OCM sector and over one-third of estimated costs for the petroleum refining sector. This reflects the basis of the monitoring regulations, which seek to accumulate data on the discharge of contaminants at several frequencies.

Another obvious difference between these two sectors is the variation between costs associated with flow measurement and reporting. The OCM sector cost estimates allocate fewer resources for these two activities because, presumably, the MISA subject firms in the OCM sector have in place adequate monitoring devices and personnel trained to take and measure samples. The petroleum

Figure 8

Costs by Monitoring Function



Source: MOE [8,15]

refining sector must invest more resources in providing an adequate level of measuring capabilities.

The total and median costs of monitoring for the first two industrial sectors subject to MISA are shown in Table 7.

Table 7
Comparison of Total Monitoring Costs
($000's)

	Organic Chemicals	Petroleum	TOTAL
Capital	$ 2,237	$ 1,575	$ 3,812
Operating	6,710	1,936	8,647
TOTAL	$ 8,947	$ 3,511	$12,459
Median	$ 243.5	$ 470	

The differences in total costs can be attributed to several factors, including:

- the difference in the number of plants in each sector. There are 19 plants in the organic chemical manufacturing sector, as opposed to 7 in the petroleum refining sector;
- the organic sector has monitoring requirements tailored to each individual plant and each individual final discharge point; and
- the number of streams to be monitored and the variety of production processes in the OCM sector are greater than the petroleum refining sector. Hence, contaminants are more complex in the organic sector, resulting in higher monitoring costs.

Future work involves the monitoring of actual costs incurred by each firm, as discussed in Section 5.

5.0 FUTURE ANALYTICAL WORK

As of writing, only one sector, petroleum refining, has had its monitoring regulation promulgated. Work on the remaining sectors is ongoing, with the economic analytical portions proceeding concurrently.

Upcoming economic work will involve assembling the information and data needed to construct monitoring and abatement functions for specific establishments or firms. The cost functions can then be used to estimate the total costs of the specific monitoring and effluent limits regulations for each industrial and municipal sector.

Abatement technologies and costs will be gathered initially through a generic study which will collect information on available technologies, their compatibility with different industries, their process capabilities and efficiencies, their current degree of usage by industries, and their associated capital and operating costs.

The aim of this phase of economic work is to develop a least-cost abatement cost functions which can specify a set of technology combinations that achieve desired abatement objectives at the lowest cost possible given available technologies. There are likely to be different combinations of technologies that can achieve the same level of abatement, but at higher costs. The development of a cost function will identify the combination of technologies that will achieve specific levels of reduction at the lowest cost.

An "abatement cost function" shows different levels of final effluent that can be achieved at specific levels of cost. Such data can be shown in a tabular format, comparing "best available

technologies" emission reduction standards to the present values of reducing discharges by given percentages.

A model has been developed by the Policy and Planning Branch, and is known as "WATAP" (Waste Treatment Analysis Program), which was presented to the Technology Transfer Conference in 1986 (Donnan[7]). This model can be used to generate abatement cost functions for individual plants, which can be combined to produce aggregate cost functions as well as estimates of the total costs of achieving specific effluent limit objectives or technology-based requirements.

Another study that is currently ongoing involves a review of comparative discharge and emission standards between Ontario and other jurisdictions. This study will assess the resulting financial and economic impact on firms who have been subject to legislated environmental standards in other jurisdictions, primarily the United States. It will also take a look at empirical enforcement and abatement activities.

6.0 CONCLUSIONS

Economic assessments are an integral part of the MISA and other Ministry environmental policy initiatives. For direct dischargers, initial results, based on two of the nine MISA designated industrial sectors specified, indicate that the total estimated incremental costs of monitoring are about $12.5 million. Financial and economic analyses indicate that these costs will not likely compromise the economic or financial viabilities of the sectors or the individual firms for which financial data were available.

Work is currently underway to:

- update the economic profiles prepared for each sector;
- estimate the incremental capital costs associate with the monitoring regulations for the remaining industrial sectors;

- assess the financial and economic implications of the estimated monitoring costs on the sectors and individual firms within each sector;
- look at generic abatement technologies and their associated costs;
- examine comparative discharge and compliance standards in other jurisdictions, and to assess the impacts and behaviour of firms in these jurisdictions; and
- assess the combined impact of MISA and other policy initiatives on all direct dischargers.

REFERENCES

1. A.R.A. Consultants, Economic Profile of Metal Mining Sectors, May 1987, **DRAFT**, Prepared for MOE.

2. A.R.A. Consultants, Sector Profiles: Petrochemical and Organic Chemical Industries in Ontario, May 1987, **DRAFT**, Prepared for MOE.

3. The Coopers & Lybrand Consulting Group, Industrial Profile: Ontario Iron and Steel Producers, November 1987, **DRAFT**, Prepared for MOE.

4. Deloitte Haskins & Sells, Industrial Minerals Sector Profile, June 1987, **DRAFT**, Prepared for MOE.

5. Deloitte Haskins & Sells, Metal Casting Industry Economic Profile, April 1988, **DRAFT**, Prepared for MOE.

6. M.M.Dillon Consulting Engineers, "Evaluation of Municipal Sewer Use Control Options" (Phases I and II), 1988, Prepared for MOE.

7. Donnan, J. et al, "Abatement Cost Functions - the Workhorse of Environmental Management", in Proceedings of 1986 Technololgy Transfer Conference, MOE 1986

8. Ontario Ministry of the Environment, "Cost Estimates and Implications of the 'Effluent Monitoring - General' and 'Effluent Monitoring - Petroleum Refining Sector' Regulations for Ontario's Petroleum Refineries", Policy and Planning Branch, July 1988

9. Ontario Ministry of the Environment, "Economic Information Needs and Assessments for Developing MISA Monitoring and Abatement Requirements", Policy and Planning Branch, March 1987

10. Ontario Ministry of the Environment, "The Economic and Financial Profile of the Ontario Electric Power Generation Industry", Policy and Planning Branch, February 1988, **DRAFT**

11. Ontario Ministry of the Environment, "The Economic and Financial Profile of the Petroleum Refining Sector - Summary Report", Policy and Planning Branch, August 1988

12. Ontario Ministry of the Environment, "Economic Profile of the Organic Chemical Manufacturing Sector - Summary Report", Policy and Planning Branch, September 1988, **DRAFT**

13. Ontario Ministry of the Environment, "The Effluent Monitoring Regulation for the Organic Chemical Manufacturing Sector", Water Resources Branch, 1988 **DRAFT**

14. Ontario Ministry of the Environment, "Effluent Monitoring Regulations for the Petroleum Refining Sector", July 1988

15. Ontario Ministry of the Environment, "Ontario's Organic Chemical Manufacturing Sector Monitoring Cost Estimates", Policy and Planning Branch, September 1988, **DRAFT**

16. Ontario Ministry of the Environment, "A Policy and Program Statement of the Government of Ontario on Controlling Municipal and Industrial Discharges into Surface Waters", (MISA "White Paper"), June 1988

17. Ontario Ministry of the Environment, "The Public Review of the MISA White Paper and the Ministry of the Envronment's Response To It", January 1987

18. United States Environmental Protection Agency, "Economic Impact Analysis of Proposed Effluent Limitations Guidelines, New Source Performance Standards and Pretreatment Standards for the **Pulp, Paper and Paperboard Mills**", Point Source Category, Volume 1, December 1980

19. Woods Gordon Management Consultants, The Economic and Financial Profile of the Ontario Inorganic Chemicals Industry, August 1987, Prepared for MOE.

20. Woods Gordon Management Consultants, The Economic and Financial Profile of the Ontario Petroleum Refining Industry, 1987, Prepared for MOE.

21. Woods Gordon Management Consultants, The Economic and Financial Profile of the Ontario Pulp and Paper Sector, June 1987, **DRAFT**, Prepared for MOE.

APPENDIX A

SELECTED MISA INDUSTRIAL SECTORS AND FIRMS

PETROLEUM REFINING

Esso Petroleum Canada (Sarnia)
Petro-Canada Inc. (Clarkson)
Petro-Canada Inc. (Trafalgar)
Petrosar Limited (Corunna)
Shell Canada Products Limited (Sarnia)
Suncor Inc. (Sarnia)
Texaco Canada Inc. (Nanticoke)

ORGANIC CHEMICAL MANUFACTURING

B.F.Goodrich Canada Inc. (Thorold)
BTL Industries Inc. (Belleville)
Borg-Warner (Canada) Limited (Cobourg)
CanadianOxy Chemicals Ltd. (Fort Erie)
Celanese Canada Inc. (Kingston)
Cornwall Chemicals Limited (Cornwall)
Courtaulds Fibres Canada (Cornwall)
(formerly Courtaulds North America Inc.)
Courtaulds Films (Cornwall)
(formerly BCL Canada Inc.)
Domtar Inc. (Longford Mills)
Dow Chemical Canada Inc. (Sarnia)
DuPont Canada Inc. (Corunna)
DuPont Canada Inc. (Kingston)
DuPont Canada Inc. (Maitland)
Esso Chemical Canada (Sarnia)
Ethyl Canada Inc. (Corunna)
Novacor Chemicals Ltd. (Mooretown)
Polysar Limited (Sarnia)
Rohm and Haas Canada Inc. (Morrisburg)
Uniroyal Chemical Ltd. (Elmira)

APPENDIX B
INDUSTRIAL SECTOR PROFILES
TERMS OF REFERENCE

The Terms of Reference for each sector profile specified the following information requirements, which were assembled for each sector noted in Section 1:

Definition of the Industrial Sector

1. Identify the firms that comprise the sector nationally and within Ontario. List and locate the individual firms and plants relevant to the MISA program.
2. Define the key products and/or product categories for the sector and individual firms.

Market Structure Information

1. Compile statistical data on products, physical output, employment, sales revenues, input components and costs for the sector over the past 10 years, and present this information for both national and provincial aggregates.
2. Present indicators of the degree of competition (or lack of it) within the sector. Include measures of concentration, or market share, as well as the rate of entrance to and exit from the key product markets.
3. Note ownership patterns, such as the degree of foreign ownership, and the number of conglomerates versus single plant, locally owned firms.
4. Note types of market situations as they occur. For example, cases of monopolistic (single seller), monopsonistic (single buyer), oligopolistic (few sellers), or oligopsonistic (few buyers) which influence market performance and ultimately consumer prices. Provide conclusions as to the degree of control over prices exercised by member firms.

Trends and Forecasts

1. Describe and summarize trends and forecasts for key product markets. Note the key determinants of the demand for the major products of the sector.
2. Where possible, report or estimate the price elasticities of demand for representative products.
3. Discuss any important events or factors which affect the cost components of the sector. Again, include trends and forecasts of these factors.
4. Present data on representative prices for the sector, and discuss the "behaviour" and trends of these prices.
5. Comment on the conduct and performance of firms within the sector.

Financial Performance Indicators

1. Calculate financial indicators and ratios for the sector and for individual firms within the sector. In other words, one figure for the "industry", and one for each firm is required. These indicators and ratios are to be calculated for the last five (5) years for which data are available.

Extraordinary Conditions

1. Comment on any other extraordinary conditions or factors affecting the sector revealed by this research, and discuss their economic implications.

E5

THE EXTRA-STRENGTH SEWER SURCHARGE TO REGULATE INDUSTRIAL SANITARY SEWER USERS

M. Fortin, Ecologistics; G. Zukovs, Canviro Consulting Ltd.; J. Donnan and G. Zequrac, Policy and Planning Branch, Ontario Ministry of the Environment.

ABSTRACT

The extra-strength sewer surcharge (ESSS) is a charge levied against industrial users of sanitary sewers by municipal sewerage authorities as a result of the excessive strength of their wastewater discharge. This study investigates the ESSS as one of the potential mechanisms that could be promoted to control industrial sanitary discharges under the Ontario Ministry of the Environments' Municipal - Industrial Strategy for Abatement (MISA) initiative.

The study methodology includes a thorough literature review, a major national survey of municipalities in Canada, interviews with municipal staff involved in ESSS programs in Ontario and economic analyses of surcharge rates, municipal treatment costs and industrial pretreatment costs. Survey and interview data were compiled and, together with literature findings and economic analyses, were used to evaluate the advantages and disadvantages of ESSS programs. This evaluation focuses on treatment cost allocation effects, inducements for industrial pretreatment, municipal revenue impacts, impacts on municipal treatment facilities, and administrative implications. Recommendations are provided regarding implementation of ESSS programs.

INTRODUCTION

In June of 1986, the Ontario Ministry of the Environment announced the Municipal-Industrial Strategy for Abatement (MISA). The goal of MISA is the "virtual elimination of toxic contaminants" that are being discharged to surface waters by municipalities and industry (MOE, June 1986). This goal is to be achieved through the development and promulgation of regulations containing monitoring requirements and effluent limits.

The problem of industrial discharges into municipal sewage treatment plant systems was identified during the public review process as requiring greater attention by the program. The Ministry of the Environment is currently developing a Sewer Use Control Program intended to reduce industrial toxic discharges to sewer systems. The Sewer Use Control Program will include legislative amendments, implementation activities, enforcement mechanisms. The proposed program calls for the Ministry of the Environment to set province-wide discharge limits on toxic contaminants from industrial sewer users.

The extra-strength sewer surcharge (ESSS), which is the subject of this study, is one element of the proposed Sewer Use Control Program. The ESSS is a charge paid by industrial users of sanitary sewers which increases as the concentration of targeted contaminants in their waste water increases beyond a designated level. The ESSS can provide revenues to offset costs of treating industrial wastes in municipal plants. More importantly, ESSS charges can give sewer users an economic incentive to reduce their wastewater loadings.

The Model Sewer Use Bylaw revised in 1987 by the Ministry of the Environment has provision to enable a municipality to implement a sewer surcharge program for certain specified parameters (MOE, August 1988). Only five conventional pollutants would be allowed for surcharge agreements under the proposed Sewer Use Control Program: suspended solids, biochemical oxygen demand, solvent extractable matter of animal and vegetable origin, nitrogen, and phosphorous.

OBJECTIVES OF THIS STUDY

Past studies have examined the ESSS and other regulatory mechanisms to control pollution (Peat, Marwick and Partners, July 1983; Donnan and Victor, 1974). These studies provide some evidence regarding the efficacy of the ESSS but they do not document the extent to which ESSS programs are implemented in Ontario or Canada and they are not detailed enough to permit an evaluation of the ESSS as an economic incentive mechanism within MISA (Ministry of the Environment, 1987).

The goal of this paper is to contribute to the evaluation of sewer use control options by providing a detailed description and critique of the use and effectiveness of ESSS programs in Canada.

STUDY METHODOLOGY

An extensive literature search was conducted using bibliographic databases available through the Industrial and Business Information Service of the University of Waterloo. Phone interviews were conducted with provincial agency staff across the country. Following this, a questionnaire survey was sent to the engineering or works department of municipalities throughout Canada, with 5,000 or more people and which provide municipal sewage collection and treatment services (referred to herein as the "National Survey"). This amounted to 546 municipalities with a total population of 14.1 million or 64% of Canada's 1986 population. A total of 192 completed questionnaires were returned from respondents representing municipalities with a total serviced population of 10.5 million people. From among the questionnaire survey respondents, six Ontario municipalities were selected for follow-up interviews to collect detailed information on compliance (referred to herein as the "Municipal Interviews"). In addition, to the primary data collection efforts noted above, secondary data sources on treatment costs were used in an economic analysis of surcharge programs.

OVERVIEW OF THE ESSS

Charges for the use of sanitary sewers include various mechanisms such as flat fees, tax levies, fees based on the volume of water consumed or discharged and fees based on the pollutant concentration. Such charges are used to recover the costs of collecting and treating sanitary wastes. The practice of charging for sewage services goes back to the turn of the century in the United States (Lake, Hannenan and Oster, 1979) and the United Kingdom (Harkness, 1984).

In the United Kingdom, charges for industrial effluents were initially set to be proportional to discharge volume. In 1936, with the opening of the Modgen Works treatment plant in West Middlesex, an effluent charge based on both quantity and quality was introduced (Ingold and Stonebridge, 1987). By 1976, existing ESSS practices of various local authorities were codified as national guidelines for sewer use and for charges related to industrial effluents. British Regional Water Authorities now control virtually every industrial effluent discharged to sanitary sewers in Britain and can impose charges that are set to recover "the actual cost of reception and treatment of industrial effluent" (Sidwick, 1982).

While there is not the same degree of centralization and standardization in the United States as is evident in the United Kingdom, certain requirements and charges for industrial effluents are nevertheless promoted at the federal level by 1972 amendments to the Clean Water Act. According to Taylor (1972), the objectives of regulations under this act are:

- to distribute costs in proportion to benefits received;
- to assure financial capability to construct and operate facilities;
- to promote awareness of treatment costs;
- to promote volume and loading based costs; and
- to encourage self-sufficiency in sewage services.

Surveys that predate the amendment found that 20% of the reporting U.S. cities had provisions for an ESSS in their bylaws while less that 10% had actually implemented an ESSS (Public Works Engineer, 1955; Lake, Hanneman and Oster, 1979). In a more recent survey, two thirds of respondents were found to be using an ESSS (Technical Practice Committee, 1982).

While there exist significant variations in programs across national boundaries and across municipalities, all ESSS programs have certain basic features in common, namely;

- a formula for determining the total charge per unit time which identifies chargeable waste water constituents and associated charge rates;
- criteria for determining which firms are to be charged; and
- a means of assigning waste strength values to industrial discharges for purposes of charging.

APPLICATION OF EXTRA-STRENGTH SEWER SURCHARGE IN CANADA

Of the 192 respondents to the National survey, 33 reported having an ESSS program "in the books." This number represents 17% of the reporting municipalities. The communities which say they had ESSS programs are concentrated in Ontario and the Prairies, as shown in Table 1. However, of the 33 municipalities with ESSS programs, 26 had implemented monitoring and enforcement with eligible industrial sewer users (15 of these were in Ontario) municipalities have a total population of 6.2 million.

TABLE 1

USE OF AN EXTRA-STRENGTH SURCHARGE PROGRAM
BY QUESTIONNAIRE RESPONDENTS

JURISDICTION	MARITIMES	QUEBEC	ONTARIO	PRAIRIES	BR. COL.	CANADA
Number of Responding Municipalities						
Total number responding	10	25	94	40	21	192
Mun's with program in place[1]	1	1	15	14	2	33
(% of total)	10.0%	4.0%	16.0%	35.0%	9.5%	17.2%
Mun's with program implemented[2]	0	1	15	8	2	26
(% of total)	0.0%	4.0%	16.0%	20.0%	9.5%	13.5%
Service Population of Responding Municipalities						
Total for all municipalities	64,340	263,520	8,220,500	1,394,430	541,550	10,499,330
For mun's with program in place	15,000	38,000	4,850,400	1,217,250	54,200	6,174,850
(% of total)	23.3%	14.4%	59.0%	87.3%	10.0%	58.8%
For mun's with program implemented	0	38,000	4,850,400	1,216,810	54,200	6,159,410
(% of total)	0.0%	14.4%	59.0%	87.3%	10.0%	58.7%

NOTES: [1] Counts based on numbers of municipalities who provided information describing their ESSS programs (questions in Section 3A and 4, Appendix B questionnaire form)
[2] Counts based on numbers of municipalities who reported monitoring and charging activity under an ESSS program (questions 45 and 46, Appendix B questionnaire form)

SOURCE: Extra Strength Sewer Surcharge Municipal Survey

In a recent survey by LeClair (personal communication, B. LeClair, MOE 1988), 45 out of 78 reporting municipalities in Ontario indicated provisions for surcharging industrial users in their respective bylaws. Of these 45, it would appear from results of the National Survey that only 14 had implemented industrial monitoring activities and actual surcharges. Similarly, Lake, Hanneman and Oster (1979) found that, in survey of 1,160 U.S. municipalities, 20% allowed for surcharges in their bylaws but only 5% actually measured discharges and levied surcharges.

Municipalities reporting a surcharge program form a distinct subset of reporting municipalities. Secondary or tertiary treatment systems are used by 88% of these municipalities as opposed to 55% of those not using the ESSS. Municipalities with the ESSS also tend to have a larger service population with more industrial accounts; and, in fact, encompass 59% of the total reported service population though representing only 17% of reporting municipalities. The proportion of industrial establishments that are within jurisdictions using an ESSE is likely to be most closely reflected by the service population data. If this is the case then the data suggest a relatively high exposure of industry to the ESSS within our survey sample.

PROGRAM IMPLEMENTATION

The initiation of ESSS programs usually engenders opposition from industrial users in anticipation of higher costs. This opposition can be overcome during the implementation period. For instance the average program design and implementation period among questionnaire respondents lasted 17 months with industry being given almost a year of lead time to allow plant managers to adjust operations prior to being charged. In Greenboro, N.C., this adjustment was facilitated by municipal staff who assisted firms in this adjustment stage (Shaw, 1970).

In half of the reporting municipalities, an information program was mounted for industry to introduce the program and input was solicited from industry. Bubbis (1963) and Mount (1979) concluded that good communication with industry during program implementation may be worth the delays and other costs that result.

PROGRAM OBJECTIVES

Two thirds of respondents identified the fair allocation of treatment cost as their key objective. In this context, a fair cost allocation means that costs are allocated to users or user groups in proportion to the sewage treatment services received. This is consistent with the user-pay pricing principle supported by the Inquiry on Federal Water Policy (Pearse, Bertrand, Maclaren, 1985).

The survey results also showed that many municipalities (21 out of 30) implemented ESSS programs in order to induce pretreatment by sewer users. However, there was very little interest expressed in revenue generation as a motive for ESSS programs (4 respondents out of 30).

ESSS AS PART OF AN OVERALL REGULATORY STRATEGY

Over one third of respondents (13 out of 30) said that the ESSS charge was a penalty for high strength wastes. The focus on regulation was also encountered during follow-up interviews with municipal staff. For example, the Regional Municipality of Peel, set the elimination of extra-strength discharges within five years as an explicit goal. That nine out of 32 respondents reported expanding bylaw enforcement efforts while introducing the ESSE is further evidence of the regulatory motivation behind ESSS programs.

Apart from the ESSS, mechanisms reported for sewer use regulation include bylaw limitations on waste strength supported by a program of surveillance and enforcement sanctions. Bylaw limits must be found to be exceeded one or more times during surveillance before enforcement action is commences. On average, respondents to the National Survey indicated that just under four violations are required to trigger enforcement action.

Municipalities with ESSS programs in place tend to have a more extensive general program of industrial regulation. For instance, only 15% of municipalities with an ESSS program report no program for detection of bylaw violation while over 40% of those without the ESSS have no such program. Similarly, a greater number of municipalities with the ESSS report use such mechanisms as negotiations, warnings and prosecution to enforce bylaw limits when violations are detected. "Other" enforcement mechanisms that were reported include severance of service and invoicing users for extraordinary costs incurred as the result of receiving high strength wastes.

The more active regulatory stance of municipalities which have an ESSS is also reflected in the intensity of surveillance efforts to detect bylaw infractions. On average they monitor one firm out of every 3.4 industrial clients on their systems. In communities without an ESSS, one out of every 26.6 industrial clients is monitored.

ESSS PROGRAM COVERAGE

Municipalities have devised various methods or rules for identifying who is eligible for charging under the ESSS. These methods include:

- coverage of all industrial dischargers,
- establishing thresholds in terms of a minimum wastewater concentrations or volumes,
- defining eligible industrial sectors.

In Winnipeg, for example, establishments in 16 key industries have their discharge monitored by the city (Perman, 1974). Large sources are treated

in a similar manner in Greenboro, N.C., but smaller industrial sources, such as laundrys, are also brought into the ESSS program with charging of these based on representative waste strengths for classes of dischargers (Shaw, 1970). Both New York City and Los Angeles County also include classes of smaller dischargers and assume representative waste strengths for clients in these classes (Anonymous, 1971; Kremer and Glasgow, 1979).

For program coverage to be based on wastewater strength or on membership in a high waste strength industrial sector, there is usually a threshold for contaminant concentration below which waste strength is considered acceptable. Los Angeles County does not use such a threshold in its charge program; neither does Chicago (Anderson and Sosewitz, 1971). In the absence of a lower threshold, all industrial dischargers are eligible for ESSS charging. Chicago sets a discharge volume threshold, instead of a concentration threshold, below which the ESSS does not apply. Dischargers of small volumes are exempt from surcharges if a volume threshold is in place.

DETERMINING WASTEWATER STRENGTHS

Wastewater strength can be determined from monitoring data, or, where no monitoring is done, representative values for industrial sectors can be assumed. Twenty-five of 31 respondents to the National Survey rely entirely on monitoring, while only one uses representative data and five use both.

In 32 out of 33 reported cases the municipal sewage authority is responsible for sampling. Dischargers engage in sampling in 6 municipalities. In 16 out of 21 cases auditing of sample results is done by the municipality. In Windsor, municipal samples are split in certain cases to allow firms to verify municipal laboratory results.

PROGRAM SIZE

A total of 400 firms are monitored under ESSS programs covered by the survey, or an average of 12 per municipality. In 15 cases, 10 or fewer firms are monitored, in 3 cases more that 30 are monitored and the maximum number in any one program is 84 in Metro Toronto. On overage, a surcharge fee is levied against 87% of the monitored firms. Half of the respondents charged all the firms that were being monitored in their programs.

RATE STRUCTURE

Charges for extra-strength sewage are usually calculated as a charge rate multiplied by discharge flow volume over the billing period and a factor based on the strength or concentration of chargeable parameters in the wastewater. Measures of waste water concentration used in the ESSS formula may be:

- the actual concentration of the wastewater,
- the excess concentration estimated as the actual minus an

allowable or "threshold" concentration (set to zero if this difference is negative),

- the ratio of actual and threshold concentrations, or
- the ratio of excess and threshold concentrations.

Where more than one parameter is included in a rate formula, so-called "apportionment factors" are applied as coefficients by which each parameter is multiplied. Apportionment factors provide for the allocation of the charge rate across the chargeable pollutants included in the surcharge formulae. Details on surcharge formulae were reported by 31 respondents. The 31 formulae included at least one, and usually 2 or more of the following pollutant parameters:

- BOD (biological oxygen demand)
- SS (suspended solids)
- grease and oil

Other parameters reported by 6 of the 31 respondents were phosphates, phenols and COD (chemical oxygen demand). The majority of respondents (over 70%) used threshold concentrations for BOD and SS ranging from 300 to 500 mg/l. The bylaw limits for these two parameters never fell below the threshold concentration used in the ESSS formulae.

The following formulae are representative of the different types used by the responding municipalities:

Waterloo Region, Ontario:

$$ESSS = Q \times (\$.40/1000 \text{ gal.}) \times [A.F.(BOD-300)/300 + A.F.(SS-350)/350 + (phenol-1)/1]$$

[where: A.F. = apportionment factor = 0.5]

Regina, Saskatchewan:

$$ESSS = Q \times [\$0.031(BOD-300) + \$0.031(SS-300) + \$0.027(grease-100) + \$0.060(PO_4-30)]$$

Swift Current, Saskatchewan:

$$ESSS = Q \times [\$0.042(BOD) + \$0.011(SS) + \$0.046(grease)]$$

In these formulae, Q represents total wastewater discharge volume over the billing period while BOD, SS, grease and PO_4 indicate measures of actual wastewater strength. The charge rates applied to the various parameters are reported to be based on collection and/or treatment system costs. In some municipalities, rates also cover ESSS program costs or are based on revenue targets.

Charge rates for BOD range from $0.032 to $0.77 per kilogram, $0.011 to $4.42 per kilogram for SS and from $0.024 to $ 15.50 per kilogram for grease and oil. Of the two municipalities that levy charges for phenol,

one charges $0.233 per kilogram while the other charges $87.90 per kilogram. Some smaller municipalities negotiate ESSS payments directly with the industrial or commercial sewer users rather than using standard formulae.

In the National Survey, reported surcharge billings to individual establishments averaged $6,800.00 per quarter, ranging from $2,000.00 to $7,500.00.

In the survey and follow-up interviews it was found that more complex surcharge formulae deter municipal staff who have to administer the program. In one instance, this antipathy resulted in a surcharge formula being dropped in favour of a fixed annual fee negotiated with each company. Sewer users were also reported to have complained about complex formulae.

DETERMINATION OF SURCHARGE RATES

Perhaps the most complex technical task in setting surcharge rates is the apportionment of collection and treatment system component costs to each chargeable parameter. Charge rates are typically based on average unit costs for treatment. If there is only one chargeable parameter, say BOD, then the charge rate for BOD would be based on total treatment costs divided by total BOD load. With additional parameters, this simple measure of average unit cost, if applied to each parameter, would not be appropriate since it would result in charging of treatment costs several times over. Rather, total treatment costs must be apportioned to each of the chargeable parameters using factors that account for all costs

without at the same time leading to double counting of costs. The issue of how cost apportionment factors are derived is important since the basis for cost apportionment can have a significant impact on the charge faced by individual firms (Foess and Mynhier, 1983).

The most frequently encountered ESSS formula is one requiring the apportionment of costs among discharge flow, BOD and SS. There are different treatments of this case documented in the literature which place varying emphasis on system design and system function in deciding the apportionment. A representative apportionment is provided by Ingold and Stonebridge (1987).

Flow related costs	- conveyance
	- primary treatment
BOD costs	- biological treatment
SS costs	- sludge treatment and disposal

Specific apportionments will vary depending on whether capital or operating costs are involved, on the treatment system configuration, and on the judgement of the engineer doing the analysis. The Underlying difficulty with this sort of cost analysis is that the particulate fraction of BOD and the biodegradable fraction of SS are closely associated constituents of sewage that are jointly removed at different stages of the treatment process. Treatment costs for these constituents cannot, strictly speaking, be logically differentiated and any apportionment will always be somewhat arbitrary and subject to debate.

Moreover, any apportionment can introduce a degree of inequity into the charge in that industrial effluents have varying mixes of dissolved vs. particulate BOD and biodegradable vs. inorganic solids. The cost burden associated with different types of effluent will therefore vary and may not be accurately reflected in the ESSS charge rates for BOD and SS

In light of the complexity and uncertainty inherent in the cost apportionment exercise it is not surprising that National Survey responses concerning how costs are apportioned showed no clear pattern; the basis for cost allocation being:

System design considerations	- 3 respondents
Treatment system function	- 3 respondents
Design and function	- 6 respondents
Arbitrary 50/50 split	- 2 respondents
Other criteria	- 4 respondents

In the "other" category, detail was only provided for two cases in which a single cost factor was estimated and then applied to BOD or SS whichever is greater.

ECONOMIC EFFICIENCY AND ESSS RATES

Economic efficiency is often interpreted as achieving a cost-effective outcome, or in the context of this study, a least cost combination of industrial pretreatment and municipal treatment in order to attain a given level of final effluent quality.

However, economic efficiency has a broader interpretation in economic theory than cost-effectiveness; the benefits of water quality protection are considered as well as the costs of treatment. In a benefit cost framework, economic efficiency requires that wastewater treatment be provided up to the level at which the value of resulting water quality benefits are judged to be commensurate with the extra costs. Benefits may accrue to the firm or agency which incurs the expense if cost reductions or extra revenues are achieved. However, the impacts of water quality improvements are more likely to benefit the public. Agents who incur the costs of these improvements seldom realize any direct benefits and may accordingly perceive these costs as an unwarranted burden. Nevertheless, these public benefits are very real to society and should be included in public decision making.

Public benefits can often be quantified in appropriate biophysical units and/or dollar values although certain types of water quality benefits are much more difficult to evaluate.

Municipalities are not in a position to balance wastewater treatment costs against associated public water quality benefits because water quality and effluent objectives are determined by Provincial authorities. Under

prevailing regulatory procedures, municipalities are only responsible for achieving mandated water quality and effluent objectives in a cost-effective manner; accordingly, cost-effectiveness is used here as the basis for discussing economic efficiency.

Marginal costs are the incremental costs of production that are caused by incremental changes in the level of production activity. In the context of the ESSS, marginal costs should be measured as the change in operating and capital costs that occur in conjunction with increases in strength of the incoming sewage to a treatment plant.

Marginal costs provide a basis for setting ESSS charge rates that will promote economic efficiency. For example, the marginal cost of installing a phosphorus (P) removal system at a municipal treatment facility was estimated to be in the range of $3 to $10/kg P removed. Any industrial or commercial sewer user who wishes to minimize costs will choose to pay a surcharge if pretreatment costs per kg P exceed the ESSS charge. Otherwise, pretreatment will be adopted as the lowest cost option. When an ESSS charge rate for P is set based on the municipal marginal cost, P removal will then be achieved using the least-cost method whether that be by treatment at source or at the municipal plant.

It follows from economic theory that ESSS rates should be based on the marginal cost of providing the service. Where marginal costs can be estimated with some ease, as in the case of phosphorus removal, the excess chlorine demand of effluents (Olliffe, 1963), or the costs of removing grease accumulations in collectors, rates can be set on this basis.

However, separate marginal costs associated with BOD and SS removal at municipal plants cannot easily be estimated because these parameters are removed simultaneously by treatment systems. Moreover, experience has shown that the costs of operating a municipal sewage treatment plant for BOD and SS removal will depend primarily on flow. Variations in wastewater inflow strength which are within the treatment system design specifications will have a negligible impact on operating costs. Consequently, the marginal costs of incremental changes in BOD or SS loadings to the treatment plant are negligible when the plant is operating within its design capacity.

In addition to the direct or "private" costs of building and operating sewage treatment plants, environmental damages caused by pollutants which are borne by downstream users or by natural ecosystems should also be considered as part of the cost of operating the sewage treatment plant. The reduction of these damages constitutes the public benefit associated with water quality protection. Environmental damages are called "public" or "indirect" costs. If both direct municipal as well as public costs associated with a treatment plant are to be considered in setting ESSS rates, the rates would be higher than if only direct municipal costs were considered.

Imposition of higher ESSS rates than these indicated by extra treatment costs may be justified on the basis of collecting funds to pay for environmental rehabilitation or even compensation to damaged parties. However, municipalities have no incentive to add environmental damage costs to their surcharge rates unless fines, penalties, or other charges were imposed by the Province on the municipality.

INCENTIVE EFFECTS

ESSS charges can give industrial establishments a powerful incentive to implement pretreatment when the cost of pretreatment is less than the cost that would otherwise be incurred as an ESSS charge. However, decisions by plant managers regarding pretreatment of industrial sanitary discharges will be governed by a range of other factors such as:

- legal and financial implications of not pretreating
- availability of plant labour to operate a treatment system,
- nuisance caused by the treatment system, and
- availability of land to install systems.

Pretreatment costs were estimated for 28 industrial establishments for which data were collected during the municipal interviews. Estimated pretreatment costs are then compared to surcharge rates to determine if the ESSS charges actually provide an economic incentive to adopt pretreatment.

Total estimated pre-treatment capital costs for the 28 sample firms averaged $2.4M and ranged form $0.4M to $6.2M. Total annual operating and maintenance costs averaged $1.07M, ranging for $0.125M.

In contrast, annual surcharge payments by these firms averaged $74,400 and ranged from $15 to $372,700. These surcharges amount to only 9% of estimated operating and maintenance costs on average, and at the maximum, were only 43% of estimated pretreatment operating and maintenance costs.

Consequently it would appear cheaper for the affected firms to pay the ESSS than to install pretreatment. This conclusion was confirmed when estimated pretreatment operating and maintenance costs were compared to surcharge rate levels reported in the National Survey. The average ESSS rate, expressed as dollar per kg BOD discharged, was $0.264, ranging from $0.032 to $0.770. All of the reported ESSS rates were less than the estimated unit pre-treatment operating and maintenance costs for the 28 individual establishments which ranged form $1.15 to $38.71 and averaged $8.02/kg BOD removed.

In comparison, municipal treatment costs per unit of removal are considerably lower than industrial pretreatment costs(Table 2). This is the expected result given the economies of scale inherent in the abatement technologies considered in the analysis. Based on this assessment, pretreatment for BOD, and suspended solids is in fact cost effective only where large establishments discharge effluents to small municipal facilities. Otherwise, centralized treatment of BOD and suspended solids in municipal sewage treatment plants is more cost-effective. However, other contaminants such as metals and toxic organic compounds may not be amenable to removal by conventional municipal sewage treatment systems. To induce pretreatment in such cases surcharges would have to be high enough to make pretreatment or at-source removal of the contaminants less costly than payment of the surcharge.

INDUSTRIAL RESPONSE TO THE ESSS

Despite the conclusion above that ESSS charge rates are often lower than pretreatment cost rates, the survey results revealed that industrial establishments which were subject to surcharges responded by improving housekeeping practices, changing production practices to reduce flows, analyzing waste flows to verify the surcharge and installing pretreatment. Eight of the 31 firms which were discussed during follow-up interviews with municipal authorities had installed pretreatment facilities.

Table 2

MUNICIPAL COST FOR BOD REMOVAL IN MUNICIPALITIES

WITH ESSS PROGRAMS (1987 $/KG BOD)

	MAXIMUM	AVERAGE	MINIMUM
100% Apportionment of Costs to BOD	$3.77	$0.75	$0.39
50% Apportionment of Costs to BOD	$1.89	$0.38	$0.20
25% Apportionment of Costs to BOD	$0.94	$0.19	$0.10

Source - Interpreted from National Survey Data.

These responses could not have been motivated entirely by economic considerations if ESSS charges are generally lower than the cost of effluent pretreatment systems. It is possible that other regulatory pressures help to induce the decision to install pretreatment with the economic incentive provided by the ESSS being a secondary consideration. It is also likely that many of the actions taken by industry to reduce wastewater strength comprise low-cost measures that are economically justified by ESSS charges. The pretreatment costs discussed above do not consider such measures. Whatever the reason, it is apparent that the ESSS has an impact. Nineteen out of 29 municipalities with ESSS programs reported such consequences as reduced loadings of SS, BOD and other contaminants, reduced operating costs, reductions or delays in capacity expansion, or changes in hydraulic loadings.

ESSS PROGRAM COSTS AND REVENUES

Although revenue generation was not cited by survey respondents as a major program objective of the ESSS, municipalities have benefitted financially from ESSS's. Total annual ESSS revenues collected by 24 municipalities which responded to revenue questions in the National Survey amounted to \$9.1M; an average of \$380,000 per municipality.

Based on responses from 18 municipalities, ESSS program activities required an average of 4.3 person-years of effort each year. An annual average of 260 samples were analyzed in each ESSS program. Assuming a staff salary level of $30,000 per year and an analysis cost of $80.00 per sample (based on commercial lab prices for the relevant tests), ESSS programs appear to cost about $150,000 per year; well under the reported average annual revenue figure.

PREFERRED DESIGN FEATURES OF ESSS PROGRAMS

Several important design features of ESSS programs were identified. These design features must be considered in developing new ESSS programs.

For example, an ESSS program, if adopted, should be applied to all industrial sewer users which discharge the relevant contaminants. Broad coverage can be achieved if representative waste strengths and volumes are assigned to each industrial sector which discharges into the system.

An ESSS program should be kept simple and straight forward. One way of doing this is to limit charges to parameters for which there is wide agreement on measurement such as BOD (or COD), suspended solids, grease and oil and, perhaps, phosphorous and phenols.

ESSS charges should be linked to identifiable costs at municipal sewage treatment plants. The ESSS rates should be based on the extra treatment and handling costs incurred at municipal sewage treatment plants which are associated with excess loadings of the wastewater constituents in question. These charges will induce industrial sewer users to install pretreatment when they are commensurate with the capital and operating costs of pretreatment systems.

While there is considerable variation in rate structures from one municipality to another, the more frequently encountered rate structures are those in which the charge applies to the entire pollutant load or to a measure of excess load. The former approach is desirable in that it gives polluters an ongoing incentive to reduce pollutant loadings. Application of the charge rate to the entire loading will also eliminate the incentive to dilute effluents with clean water in order to reduce concentrations below a threshold (Sims, 1979).

Program implementation should involve municipal interaction with industrial establishments in order to explain the purpose of the program and provide opportunities for feedback from affected sewer users. A transition period of about 12 months is often provided during which sewer users have time to adapt to the new system and reduce their discharges before the ESSS charge comes into effect.

SUMMARY

Of the 192 respondents to the Canada-wide survey, 33 reported having an extra-strength surcharge program "on the books." Of these, 26 had implemented the program to the extent that industrial dischargers were being monitored and surcharges levied on occasion. The survey has identified virtually all of the municipalities in Canada with an active extra-strength sewer surcharge program.

Existing ESSS programs in Canada are generally located in larger urban centers where problems arising from industrial wastes in sewers are more prevalent. The programs focus on industrial establishments which are large and discharge large volume, high strength wastes. Surcharges have been established for BOD (or in some cases, COD), suspended solids, grease and oil and, in a few instances, phenols or phosphates.

Survey results show that ESSS programs have been effective in spurring dischargers to install pretreatment and to control the strength and flows of industrial dischargers to municipal sewer systems.

ESSS programs are also viewed by many municipalities as a means of equitably recovering the extra costs of treating industrial and commercial wastes in municipal sewage treatment plants.

Simple, easy to understand surcharge formulae are most preferred by municipal authorities as well as by firms who pay surcharges.

RECOMMENDATIONS

The following recommendations follow from this study:

- A model sewer-use bylaw should include provisions and guidelines for a municipality to enact and implement an ESSS program. The decision to implement an ESSS program can then be based on local conditions.

- If an ESSS program is to be effective at inducing sewer users to install pretreatment, surcharges must be commensurate with the direct capital and operating costs of the pretreatment technologies.
- A periodic sewer-use rate survey should be conducted by provincial authorities to inform interested parties about ESSS practices and to facilitate municipal ESSS program planning exercises.

- Further study of the feasibility, removal efficiencies and cost pretreatment and centralized treatment technologies relevant to toxic constituents should be initiated inorder to determine the utility of ESSS charges for there constituents.

Together with more extensive monitoring, legal prohibitions, a greater degree of municipal enforcement and prosecutions, Extra-Strength Sewer Surcharges will contribute to an improved sewer use program in Ontario.

REFERENCES

Anderson, N.E. and B. Sosewitz. 1971. "Chicago Industrial Waste surcharge Ordinance." Journal of the Water Pollution Control Federation 43(8):1591-1599.

Anonymous. 1971. "Cities Treat Industrial Waste." Environmental Science and Technology 5(10):1000-1002.

Bubbis, N.S. 1963. "Industrial Waste Control in Metropolitan Winnipeg." Journal of the Water Pollution Control Federation 35(11):1403-1413.

Donnan, J. and P. Victor. 1976. "Alternative Policies for Pollution Abatement: The Ontario Pulp and Paper Industry" Ontario Ministry of the Environment.

Foess, G.W. and M.D. Mynhier. 1983. "Experiences with User Charge Litigation" presented at the 56th Annual Conference of the Water Pollution Control Federation, Atlanta, Georgia.

Harkness, N. 1984. "Problems Associated with the Disposal of Trade Effluent to Sewers - Charging and Control." Water Pollution Control 83(3):367-375.

Ingold, N.I. and N.G. Stonebridge. 1987. "Trade Effluent Charging - The Mogden Formula." Water Pollution Control. pp. 172-183.

Kremer, J.G. and D. Glasgow. 1979. "Industrial Waste Surcharge Program in Los Angeles County." Journal of the Water Pollution Control Federation 51(11):2626-2635.

Lake, E.E., W.M. Hanneman and S.M. Oster. 1979. Who Pays for Clean Water? The Distribution of Water Pollution Control Costs. Westview Press, Boulder, Colorado.

Mount, T.L. 1979. "A Municipal Program to Control Industrial Waste." Presented at American Institute of Plant Engineers Water Pollution Contamination Control Conference, New Jersey, April 10.

Olliffe, J.J. 1963. "Sewer Service Charges and Surcharges." Journal of the Water Pollution Control Federation 35(5):607-613.

Ontario Ministry of the Environment. 1987. "Economic Information Needs and Assessments for Developing MISA Monitoring and Abatement Requirements." Corporate Resources Division.

Pearse, P.H. F. Bertrand, and J.W. MacLaren. 1985. "Currents of Change." Final Report, Inquiry on Federal Water Policy, Ottawa.

Peat Marwick and Partners in association with W.A. Sims. 1983. Economic Incentive Policy Instruments to Implement Pollution Control Objectives in Ontario. Toronto: Peat Marwick and Partners.

Perman, A. 1974. "The Experience with the Effluent Charge Scheme of the City of Winnipeg." Presented to Department of the Environment, Hull, P.A., Reproduced in J. Donnan and P. Victor, 1976. "Alternative Policies for Pollution Abatement, The Ontario Pulp and Paper Industry." Vol. 2, Ontario Ministry of the Environment.

Public Works Engineer. 1955. "Industrial Waste Disposal Charges in Cities over 5,000 Population." Special Report no. 18-5, American Public Works Association.

Shaw, R.E. 1970. "Experience With Waste Ordinance and Surcharges at Greenboro, N.C." Journal of the Water Pollution Control Federation 42(1):44-50.

Sidwick, J.M. 1982. "The Discharge of Industrial Effluents to the Public Sewer." In Volume 1 of Water Resource Management in Industrial Areas, International Water Resources Association Report. pp 376-384.

Sims, W.A. . 1979. "The Response of Firms to Pollution Charges." Canadian Journal of Economics, XII(1):57-74.

Taylor, C.C. 1972. "Industrial Waste Treatment Charges for Users as Required by the Environmental Protection Agency." The Georgia Operator. Spring.

Technical Practice Committee. 1982. "Sewer Charges for Wastewater Collection and Treatment - A Survey." Water Pollution Control Federation, Washington, D.C.

E6

A STUDY OF THE ECONOMIC FACTORS RELATING TO THE IMPLEMENTATION OF RESOURCE RECYCLING OR ZERO-DISCHARGE TECHNOLOGIES FOR HEAVY METAL GENERATING INDUSTRIES IN CANADA

Bernard Fleet and Jay Kassirer, Chemistry Department, University of Toronto, Toronto M5S 1A1; and TRSI/SCADA Systems Inc., 44 Fasken Drive #14, Rexdale M9W 5M8.

and

Toby Sanger and Terrence Burrell, VHB Research and Consulting Inc., 720 Spadina Avenue Suite 509, Toronto M5S 2T9.

1. INTRODUCTION AND OBJECTIVES

The Environmental Challenge

The safe management of hazardous chemical wastes is one of the major challenges facing modern society (1). While synthetic chemicals are an essential part of modern life, there is rapidly growing public awareness and concern that the many industries are not managing their hazardous wastes as effectively or as safely as is at present technically or economically feasible.

Traditionally, land disposal has been the major treatment approach for toxic wastes. This has created two major problems; first, runoff from landfills has contaminated large numbers of drinking water supplies and second, there has been the discovery of large numbers of abandoned chemical dumps. The extent of the problem is most visible in the US. The Federal Government $10 billion "Superfund" program was authorized to start cleanup at some of the more dangerous of the 17,000 chemical dump sites identified by the Environmental Protection Agency (EPA).

Other estimates claim that the real number of sites is close to 1/4 million and that $100-200 billion is a more realistic estimate of cleanup costs. Other industrialized countries face similar problems with West Germany recently allocating $5 billion to clean up 2000 of its 20,000 dump sites. The Netherlands, similarly estimates its cleanup bill to be as high as $7 billion. Despite the risks associated with land disposal of hazardous wastes most industrialized countries including Canada still rely heavily on this approach. The United Kingdom, for example, still ships over 75% of its toxic wastes to landfill sites.

Canada also has a strong dependence on the land disposal of chemical wastes, with its two largest chemical waste management companies being landfill operators. A major Ontario major environmental initiative, the Ontario Waste Management Corporation is also basing its final waste management solution on the land application of incinerator ash and metal sludges.

Although there is now clear evidence that converting liquid or airborne pollutants into a solid waste is merely postponing the real solution of the problem, land disposal continues to be a very attractive option because of its low cost and technical simplicity.

Waste Minimization

Fortunately, along with the EPA and other U.S. state environmental agencies the Ontario Ministry of the Environment is following a more enlightened path and is exploring a much wider range of waste management options. Under the MISA program (2), a major effort is being made to persuade industries to implement a waste reduction or waste minimization program as a first step and to support this wherever possible with the remaining 3R's of the 4R strategy; reuse, recycle and recover.

Waste minimization has undoubtedly been one of the most significant developments in the field of hazardous waste management (3-7). Following the EPA's report to Congress (3), the Office of Technology Assessment has published a detailed survey of waste minimization approaches (4). Some 30 States in the U.S. (6) now have active programs of technical and financial support for companies seeking waste minimization guidance. Many of these programs provide detailed waste audit and waste minimization manuals (7).

Objectives of the Study

There are two major factors which influence a company's decision to invest in a waste management system (or upgrade an existing installation). The first, most critical factor is the environmental legislation in force, or more specifically the actual level of enforcement of that legislation. While many regions have comprehensive environmental legislation, enforcement of these laws often at local level varies widely. The recent trend towards imposition of criminal rather than civil liabilities for pollution offences, however, is significantly increasing industry's general level of responsiveness. The second factor, and the subject of this study, is the economics of the various alternative waste management strategies or technologies.

The critical task for any company facing a chemical waste management problem is to select effective treatment technologies and implementation strategies which are both technically and economically viable. Furthermore, since plants may have a lifetime in excess of 10 years, a new waste treatment system must also be capable of meeting future expansion and possible changes in environmental legislation.

Estimating the performance and costs of different waste management options is a complex task requiring information that is difficult to obtain and which is often unreliable and inaccurate. The objective of the present study (8) was to take one major category of hazardous waste, toxic heavy metals, and to compare the costs of the various waste treatment technologies and management strategies. In order to do this it was necessary to focus on certain industries that are generators of toxic metal bearing waste streams and to relate the study to the specific operating practices and manufacturing processes of each. The metal finishing, printed circuit board manufacturing and gold milling industries were selected.

A major focus of the present study was the development of an economic model which would allow a cost comparison of alternate waste management strategies, both from a private and from a social perspective. In addition, the model was designed to predict the economic effects of various future environmental scenarios such as increased land disposal costs, increasing water costs and stricter discharge standards.

Waste Management Technologies and Strategies

Traditionally, heavy metal wastes from the metal finishing and electronics products industries have been treated chemically (9). Addition of lime, caustic or another treatment agent, converts the dissolved metals to a solid 'sludge'. This sludge is usually filtered, the solids partially dewatered and the resulting solid waste material shipped to a land disposal site.

During the past 15 years a number of alternate treatment technologies have emerged (9-18), mostly based on physicochemical principles, which aim to recover the toxic metals in the waste stream for possible resale as scrap, reuse in the manufacturing process or at the least for safe disposal. Such techniques as evaporation, adsorption, ion-exchange, various membrane separation technologies (including, reverse osmosis, ultrafiltration electrodialysis and coupled membrane transport) electrolytic recovery systems (including electrowinning and high performance electrode cells) and biotechnology have all found application. Despite some early setbacks and technical problems, most of these techniques have now been successfully field demonstrated in a range of pollution control applications.

The various treatment technologies may be used individually to treat specific waste streams (point source treatment), or they may be integrated with one another and with ancillary equipment to provide a turnkey, often end-of-pipe treatment process. In addition, these technologies and processes can be adapted for use in various treatment strategies. Typical strategies include:

* Offsite transport and land disposal
* Onsite treatment
* Offsite transport to a centralized treatment facility
* Onsite treatment with a transportable treatment unit (TTU)

Treatment of hazardous metal bearing wastes using the latter three strategies can be further broken down into two major approaches:

* Traditional, chemical "sludge" treatment usually depending on offsite transport to a landfill facility or occasionally a metal refiner
* Resource recovery and recycling. Also known variously as zero-sludge, zero-discharge or the 4R's approach (reduce, reuse, recover or recycle).

Onsite treatment and recovery has a major benefit that under optimum conditions the plant no longer is a generator of hazardous wastes and so eliminates all liability and costs for offsite waste transport and disposal.

A variant of the onsite treatment approach is the transportable treatment unit (TTU) concept where a mobile waste treatment unit is brought into the plant on an intermittent basis to treat collected wastes (19). This strategy is highly attractive for the treatment of low volume, highly toxic or concentrated waste streams; incineration of polychlorinated biphenyls (PCB's) is a case in point. TTU's are generally unsuitable for the treatment of large volumes of dilute waste streams such as electronics or metal finishing process rinses, on both logistical and economic grounds.

A third strategy is the centralized treatment approach. Despite the success of this route in Europe (20) there has been strong public opposition to facility siting here in North America. Although under carefully monitored and controlled conditions this approach may be beneficial for the treatment of certain special categories of wastes, social and political hurdles seriously place in doubt the ability of this route to make a significant contribution to the overall waste management problem. There are, however some promising examples of smaller, more specialized centralized treatment plants, one of which has been used to treat the wastes from a number of metal finishing operations (21). The approach may also have some relevance in the case of small quantity generators (22).

2. ECONOMICS OF WASTE MANAGEMENT

The economics of hazardous waste management are complex. From a private perspective, waste management strategies rarely contribute directly towards profits. Most companies view waste management as an added cost of manufacturing, often resenting the fact that it is also a cost that many competitors in less developed, less environmentally sensitive countries do not have to bear. From a social perspective there are additional cost factors which do not effect individual firms, but which are of concern to society at large. These 'externalities', which are often difficult to estimate, include the public cost to treat industrial discharge, the effects of the treated waste on the public (e.g. reduction of land values near landfill sites) and possible future cleanup costs.

There have been a large number of reported studies of the economics of waste management (1,3,5,10,11,16-27). These have included several general assessments of waste management economics, including water costs, economic impacts of land disposal restrictions, problems of interstate or transboundary shipments and the costs of landfill reclamation (23-27). Most of the economic studies which relate to heavy metal management have been focussed on the metal finishing industry (27-32). A further group have examined regional or industry specific situations such as the California electronics and printed circuit board industries (16,33-35). An additional source of data are the various case studies which are either plant or technology specific and mostly prepared by manufacturers (36-38).

Despite the wealth of waste management cost data in the literature, estimating the costs of various methods of treatment and disposal remains a complicated task requiring information that is often difficult to obtain and which is often unreliable and inaccurate. Different estimates may employ different assumptions, certain costs may be excluded and the accuracy of the data may also vary. In some cases the underlying assumptions are not defined, making it difficult to compare two estimates that have been prepared differently. The cost estimates based on manufacturer's equipment price quotes are unreliable partly due to lack of detail and in part due to the site specific variability of the cost. In general capital costs are more reliable than operating costs.

There are several studies which are relevant to the present project (16, 28-32, 35). The EPA study carried out in 1979 (28) is now quite outdated, however, the more recent effluent limitations guidelines (29) provides a wealth of cost data on alternate technologies. Duffy et al (32) have reviewed waste management costs for conventional waste treatment for 14 metal finishing plants in the Minneapolis region. This work was carried out in order to provide baseline data for a proposed centralized metal finishing waste treatment facility for the Minneapolis metropolitan area (21). The study which surveyed plants ranging from 1,000 to 200,000 gallons per day of process flow has provided valuable data on capital and operating costs for conventional treatment systems.

Schwartz et al (35) have carried out a very detailed study of waste management strategies and economics for California's electronic industry. While this study does not provide the wealth of case study detail of the previous work, it does present a much deeper assessment of economic factors including possible tax incentives and other measures which might improve the level of acceptance of alternatives to land disposal.

The study by Judd, Fleet et al (16) for California Department of Health Services, Alternative Technology Division, surveyed waste reduction strategies for the Printed Circuit Board Industry. After reviewing resource recovery technologies and implementation strategies, the report presented a preliminary cost comparison of a zero-discharge, maximum water recycling waste treatment system and a conventional "sludge" treatment installation, both for plants with similar operating practices and total process water flow of 100,000 gallons per day. In addition a comparison was also made with the data obtained by Duffy et al (32) after scaling the costs for each site to a flow rate of 100,000 g.p.d.

This study did not include the impact of intangible costs such as insurance, legal liability, etc., which favor the zero-discharge approach. Nonetheless, it demonstrated that given the stringent environmental conditions in California, resource recovery waste management systems are more cost effective than conventional treatment systems for facilities having daily process water flows in excess of 100,000 gallons. With increasing water costs and decreasing availability of landfill sites, it was predicted that the break even point would move steadily towards smaller and smaller plants.

While all of these studies provided valuable data, none of them furnished an economic model that could be used by waste generators, government agencies, and other researchers, to evaluate alternative waste management options and costs for a particular site, or evaluate the impact of varying economic, legislative and operating conditions.

3. AN ECONOMIC MODEL

Introduction

An economic model was prepared by VHB Research and Consulting, in conjunction with TRSI/SCADA Systems, to serve as an analytical tool for two purposes:

1. To estimate the costs of alternate waste management systems to firms in the metal finishing and printed circuit board industries.

2. To estimate some external costs (primarily through subsidized water rates and environmental impacts - which do not enter into an individual firm's economic calculations), and to estimate the costs of alternate waste management systems from a social perspective.

The model provides detailed output information over a 20-year period for the systems being analyzed. Itemized pre- and post-tax data can also be generated. The model is designed to analyze the costs of alternate waste treatment systems. Although the default comparison is between a "zero discharge" system and a "conventional" sludge precipitation system, any two types of systems can be compared if the user provides capital and annual operating cost information for each.

Costs to Individual Firms

Model inputs for the analysis of costs to the firm include capital costs and a full range of operating costs. Capital cost inputs can be disaggregated to separately account for direct equipment costs, direct installation costs, engineering and design costs, contingency costs, and salvage values for more detailed tax and depreciation calculations.

The range of annual operating costs accounted for include: labour, electricity, water supply, water discharge, chemicals, maintenance, manifesting/paperwork, insurance, storage, and costs of sludge transportation and disposal.

The model allows for different depreciation rates, different loan rates and conditions, variable inflation rates, provision for provincial and federal grants to the firm, and evaluation over different time horizons. A "switch" is provided in the computer program to include the capital and operating costs of a water demineralization system, as most Printed Circuit Board plants (and some metal finishing plants) require de-ionized water for rinsing and reconstituting baths.

Survey data from over 40 metal finishing and printed circuit board manufacturers in Ontario were collected and tabulated as part of the study to provide a basis for the estimates of cost variables for conventional sludge precipitation waste management systems. Published estimates of these costs, and engineering cost estimates provided by equipment manufacturers/suppliers, were also considered. The default set of capital and operating costs were estimated from these data, using linear regression techniques to obtain functions relating these costs to an indicator of the magnitude of waste treatment streams. Capital costs were estimated as a function of GPM water usage whereas most operating costs were estimated as a function of annual water usage.

Social Costs

The main external costs associated with waste disposal by heavy metal generating industries in Canada include: public subsidization of water supply and disposal; environmental, health, and social impacts of sludge disposal; environmental and health impacts of water contamination, and public monitoring costs.

The external costs of land disposal of sludge and public subsidization of municipal water supply and treatment for industry were both estimated and included in the model as defaults as external costs. These values were estimated as averages for Ontario or Canada per tonne of waste disposed at municipal landfills or per thousand gallons water supplied or discharged.

Testing of the Model

Linear regression estimates for the slope parameters for many of the cost variables demonstrated satisfactory coefficients of determination (R^2) at a 95% probability level, although the intercept estimates were generally insignificant. The model proved to be robust. A sensitivity test of the model estimates using estimated standard errors yielded a wide maximum range for model output. Despite the wide maximum range calculated for these estimates, simulation comparisons demonstrated that the model estimated total and individual costs very close to those reported in published case studies.

4 APPLICATION OF THE MODEL: ECONOMICS OF ZERO DISCHARGE IN THE METAL FINISHING AND PRINTED CIRCUIT BOARD INDUSTRIES

Approach

Metal finishers and printed circuit board manufacturers are being faced with increasing pressure to reduce the quantities of toxic metals discharged to sewer, and also to minimize or eliminate the amount of sludge they produce. The economics of implementing waste treatment systems that minimize or eliminate waste production (zero discharge systems) were investigated using

the model. The question posed was the following: faced with construction of a new plant or installing a new waste treatment system, how do zero discharge systems compare with conventional (sludge based) systems from an economic point of view?

Default settings were employed, with the following assumptions:

working days per year	250
hours per day	16 (Figure One) or 20 (Figure Two)
time frame	10 years (amortization period same)

Figures 1 and 2 provide a financial summary of the results. Two measures of economic comparison are presented. The first, internal rate of return, is a measure of how profitable the investment in a zero-discharge system would be. It compares the annual savings in operating expenses with the higher capital costs of the zero-discharge systems, and represents these savings as a rate of return on the initial investment (the investment is the additional capital costs incurred). The internal rate of return can be thought of as the 'interest rate' provided by the investment.

The second measure of economic comparison is the discounted payback period. This measure indicates the number of years required before the annual savings exceed (or 'pay back') the initial investment. This is a critical figure for industry, as most firms are unwilling to undertake an investment which will not pay for itself within three years, even if the investment offers a reasonable rate of return in the long run.

Results and Discussion

1. Medium to large printed circuit board manufacturers (100,000 gpd or more of process water) operating 20 hours per day can realize substantial cost savings from implementing zero discharge systems, with payback periods of 2-3 years and an after-tax return of 31% - 41% on their investment.

2. The situation is less promising for plants operating at 16 hours per day. Although after-tax returns of 21% - 41% are realized (representing a reasonable return on investment for most firms), after-tax payback is always over 3 years. However this assumes present cost structures; increases in the cost of water/sewage and sludge disposal would make the investment more profitable and would lower the payback period.

   The reason why a reduction in hours worked per day has such a dramatic impact on the economic picture is as follows: An increase in a plant's flow rate (gpm) is required in order for it to operate at the same daily water volume (gpd). This calls for a larger waste treatment system. The larger the system the greater the cost, and the greater the additional investment required to purchase a zero-discharge system. The additional yearly maintenance costs are therefor increased as well. Furthermore, a reduction in the hours worked per day diminishes the labor savings from the zero-discharge system.

3. Small printed circuit board plants can not afford to implement zero-discharge systems of the sort discussed in the report, given present

FIGURE 1

FINANCIAL SUMMARY FOR PLANTS OPERATING 20 HOURS PER DAY

SCENARIO		PROCESS WATER FLOW									
	,000 GPD	40	50	75	100	125	150	175	200	225	250
	GPM	34	42	63	84	105	126	147	168	189	208
PRINTED CIRCUIT BOARD PLANT/ WITH WATER DE-IONIZATION											
PRIVATE COSTS ONLY											
Pre-tax rate of return (%)		-1	15	32	40	45	48	50	52	53	54
After-tax rate of return (%)		-1	12	25	31	34	37	38	39	40	41
Pre-tax payback period (years)			7	4	3	3	2	2	2	2	2
After-tax payback period (years)			8	4	3	3	3	3	2	2	2
SOCIAL AND PRIVATE COSTS											
Pre-tax rate of return (%)		6	21	37	45	50	53	55	57	58	59
After-tax rate of return (%)		5	17	30	35	38	40	41	42	43	44
Pre-tax payback period (years)		14	6	3	3	2	2	2	2	2	2
After-tax payback period (years)		17	6	3	3	3	2	2	2	2	2
METAL FINISHING/ WITHOUT WATER DE-IONIZATION											
PRIVATE COSTS ONLY											
Pre-tax rate of return (%)		-25	-4	12	20	25	29	31	33	35	36
After-tax rate of return (%)		-7	-4	10	16	20	22	24	25	27	27
Pre-tax payback period (years)				9	6	5	4	4	4	3	3
After-tax payback period (years)				10	7	5	5	4	4	4	4
SOCIAL AND PRIVATE COSTS											
Pre-tax rate of return (%)		-14	0	16	24	29	32	35	37	38	40
After-tax rate of return (%)		-12	0	13	19	23	25	27	28	29	30
Pre-tax payback period (years)				7	5	4	4	3	3	3	3
After-tax payback period (years)				8	6	5	4	4	4	3	3

FIGURE 2

FINANCIAL SUMMARY FOR PLANTS OPERATING 16 HOURS PER DAY

SCENARIO		PROCESS WATER FLOW									
	,000 GPD	40	50	75	100	125	150	175	200	225	250
	GPM	46	52	78	104	130	156	182	208	234	260
PRINTED CIRCUIT BOARD PLANT/ WITH WATER DE-IONIZATION											
PRIVATE COSTS ONLY											
Pre-tax rate of return (%)		7	14	23	27	29	31	33	33	33	34
After-tax rate of return (%)		6	12	18	21	23	24	26	26	27	41
Pre-tax payback period (years)		13	8	5	4	4	4	4	4	4	3
After-tax payback period (years)		15	9	6	5	4	4	4	4	4	4
SOCIAL AND PRIVATE COSTS											
Pre-tax rate of return (%)		14	18	26	30	33	34	35	36	37	37
After-tax rate of return (%)		10	15	21	24	26	27	27	28	29	229
Pre-tax payback period (years)		9	6	4	4	4	4	3	3	3	3
After-tax payback period (years)		10	7	5	4	4	4	4	4	4	3
METAL FINISHING/ WITHOUT WATER DE-IONIZATION											
PRIVATE COSTS ONLY											
Pre-tax rate of return (%)		-11	-3	7	11	14	16	18	19	20	21
After-tax rate of return (%)		-9	-2	5	9	11	13	14	15	16	16
Pre-tax payback period (years)				13	9	8	7	6	6	6	6
After-tax payback period (years)				10	8	7	6	6	5	5	5
SOCIAL AND PRIVATE COSTS											
Pre-tax rate of return (%)		-7	0	10	14	17	19	21	22	23	34
After-tax rate of return (%)		-6	0	8	11	23	25	27	28	29	30
Pre-tax payback period (years)				10	8	7	6	6	5	5	5
After-tax payback period (years)				12	9	8	7	6	6	6	6

cost structures. These firms will probably want to implement waste reduction measures stepwise by incorporating recovery technologies on selected waste streams and by reducing their dependence on conventional sludge-based treatment systems.

4. Metal finishing plants must be larger than printed circuit board plants to realize similar financial returns from investing in zero-discharge systems. The reason is as follows: Most metal finishing plants do not require a water de-ionization system and therefore the model does not include the costs of such a system in the comparison. The zero-discharge system (with its ability to recycle process water as de-ionized water) is therefore compared with a conventional system with no water recycling. This reduces the cost of the conventional system but not that of the zero-discharge system, making the zero-discharge systems less desirable from an economic point of view.

5. It is interesting to note that the present tax structure discourages plants from adopting zero-discharge technologies. The higher operating expenses of conventional systems provide firms with greater tax shelter. This suggests that tax incentives might be an attractive option available for government to encourage companies to reduce their waste generation.

6. From a social perspective, the case is strong for encouraging zero-discharge systems. For printed circuit board manufacturers using 40,000 gpd or more, and for metal finishers using 75,000 gpd or more, there is a positive return on investing in this type of waste treatment. This finding supports current regulatory trends to assist industry in implementing zero-discharge systems.

5. APPLICATION OF THE MODEL: CASE STUDY OF A PRINTED CIRCUIT BOARD MANUFACTURER

Approach

The model was applied to an Ontario printed circuit board manufacturer, using actual cost data derived from the firm. Again, the question was raised: faced with construction of a new plant or installing a new waste treatment system, how would a zero discharge system compare with a conventional (sludge based) system from an economic point of view?

Site Description

The site is a large captive printed circuit board manufacturing facility located in Southern Ontario. The main features of the site are summarized on the following page:

Shop Type	Printed Circuit Board Captive Shop
Plated Board Area	current- 4,000 sq.ft./day targeted-5,200 sq.ft. by end of the year
Type of Boards	mainly double sided boards with some multilayer and single-sided boards.
Metals Plated	electrolytic (acid) copper, chelated (electroless) copper and tin/lead
Work Day	two 8-hr shifts plus an additional half shift (4-hours) for the electroplating line.
Daily Water Usage	250,000 US gallons per day (g.p.d.).

Results and Discussion

Figure 3 is an output summary provided by the model. The top section lists the key operating conditions; the middle section summarizes each cost category and the resulting annual costs; the bottom section provides a financial comparison of the two systems before and after tax considerations.

For a printed circuit board firm of this size, the zero-discharge system is clearly a wise investment. It provides an internal rate of return of 32% (after tax) and a payback period of 3 years, even without taking into account future increases in the cost of water (influent water and effluent to sewer) and sludge disposal.

The **increased expenses** associated with the zero-discharge system are:

1. **An additional $813,000 to purchase the system.**

2. **An additional $60,000 yearly for maintenance.** This difference is abnormally high due to the fact that the case study firm reported maintenance costs for its current installation that were much lower than the industry average.

3. **An additional $29,000 per year for electricity,** to run the electrorecovery cells.

FIGURE 3

PRIVATE COST SCENARIO

Daily Water Use:	250 000 Gals	Gallons per Minute	212
Evaluation Horizon	10 Years	Annual Water Use (million)	75
Discount Rate	10.0%	Water & Sew. Cost/1000 gal	$2.71
Corporate Tax Rate	51.0%	Disposal Cost (per tonne)	$102
Interest Rate	7.0%	Inflation Rate	0.0%
% Owner's Equity	100.0%	Grants - Provincial	0
Daily Operation	20 Hours	- Federal	0
Working Days/Year	300 Days		

Capital Costs	Zero-Sludge	Conventional
Total Installed Cost	2,309	1,496
Annual Capital Cost	329	213
Annual Operating Costs		
Maintenance	92	32
Labour	101	158
Chemicals	67	229
Electricity	34	5
Water/Sewage	20	203
Waste Disposal	0	29
Other	1	5
Total Operating Cost	316	661
Total Annual Cost	645	874
Annual Social Costs	0	0
PreTax Net Present Value	4,250	5,557
AfterTax Net Present Value	2,228	2,829

Comparison of Systems	Pre-Tax	After-Tax
Net Present Value	1,306	601
Internal Rate of Return	41.07%	31.62%
Annual Payment	(213)	
Payback Period	3	3

These were more than compensated for by the following **savings in operating expenses**:

1. **Savings of $47,000 per year in labor** (including overhead).

2. **Savings of $162,000 per year in chemicals**. This is an unusually high difference, as the case study firm reported chemical costs that were much higher than average. Cost savings normally derive from elimination of the flocculants used in creating sludge.

3. **Savings of $183,000 per year in water and sewage use costs**. The case study had water and sewer use rates that were 91 cents (per thousand gallons in and out) lower than the survey average. A rate increase of 91 cents would bring the savings up by $61,000 to $244,000 per year. Expected increases in this area will make a zero-discharge system even more attractive.

4. **Savings of $29,000 per year in sludge disposal**. This is unusually low, because the case study plant generated less sludge than would be average for a plant using 250,000 gpd of water. Note too, that the plant was paying only $102 per tonne for disposal. In the US, the industry average is $CAN 250-500 per tonne and is rapidly escalating. Much higher sludge disposal rates can be expected for Ontario firms in the near future.

6. CONCLUSIONS

The major conclusions of the study are as follows:

1. A viable economic model has been generated for evaluating the economics of alternative chemical waste treatment technologies. This model includes a default estimation of the private and social costs relevant to conventional (sludge based) and zero-discharge (resource recovery) waste treatment strategies, for metal finishers and printed circuit board manufacturers in Ontario. The model proved to be robust and accurate when tested.

2. The present paper applies this model in two ways. First, the model is used to provide an overview analysis of the comparative economics of conventional and zero-discharge waste treatment strategies for metal finishers and printed circuit board manufacturers of various sizes. This approach provides environmental policy makers with firm economic data on which to base policy decisions. It can also assist environmental funding agencies in designing cost effective incentives programs.

3. Second, the model is applied to the particular case of a medium to large sized printed circuit board manufacturer. This approach is useful for individual companies wishing to evaluate the costs of purchasing alternative waste treatment technologies. It can also assist environmental funding agencies in applying incentives to particular sites.

4. Some large plants can realize substantial cost savings from implementing zero-discharge strategies, with payback periods of less than three years and after-tax rates of return of up to 41%. While the majority of plants would

save money through zero-discharge, payback periods of over three years would deter many firms from adopting these strategies.

5. Zero-discharge systems have higher capital costs, and correspondingly higher maintenance costs. However, these are usually more than compensated for in the long run by savings in water, sewage use, sludge disposal, labor, and chemical costs.

6. It was noted that the present tax structure discourages plants from adopting zero-discharge technologies. This suggests that tax incentives might be an attractive option available for government to encourage companies to reduce their waste generation.

7. From a social perspective, the case is strong for encouraging zero-discharge systems. For printed circuit board manufacturers using 40,000 gpd or more, and for metal finishers using 75,000 gpd or more, there is a positive return on investing in this type of waste treatment. This finding supports current regulatory trends to assist industry in implementing zero-discharge systems.

8. Although initial testing and applications of the model are very promising, the following refinements would make the model of even greater assistance.

* An expanded survey should be carried out to obtain a larger sample which can be stratified to improve cost estimates at a disaggregated level for different waste treatment processes.

* Results from this improved survey database should be compared and contrasted with waste treatment cost estimates from more manufacturers for installed systems.

* More accurate estimates of the probability distributions are needed for the model parameters, as is an estimate of confidence intervals for the output using a Monte Carlo simulation.

* A more detailed study of external costs should be conducted with special emphasis given to estimating the costs of water supply, municipal wastewater treatment for various plant discharges, environmental and health costs of heavy metal effluent, possible future cleanup costs, and to public monitoring costs. These external costs and subsidies should be estimated with reference to their jurisdiction: whether they are subsidies from or costs to municipal, provincial or federal levels of government.

* The model could be applied to other categories of waste management involving different technologies and strategies.

A more detailed discussion of alternative technologies, economic factors, and of the model and its application, can be found in the full report on this project, submitted to the Ontario Ministry of the Environment (39).

7. REFERENCES

1. World Resources 1987, The International Institute for Environment and Development, and the World Resources Institute, Basic Books, New York, 1987.

2. Municipal Industrial Strategy for Abatement, White Paper, Ontario Ministry of the Environment, 1986.

3. Report to Congress:Minimization of Hazardous Waste, Vol I & II, U.S. Environmental Protection Agency, EPA/530-SW-86-033A, 1986.

4. U.S. Congress, Office of Technology Assessment, Serious Reduction of Hazardous Wastes:For Pollution Prevention and Industrial Efficiency, OTA-1TE-317 (Washington, DC: US Government Printing Office, 1986.

5. M.E.Campbell and W.M.Glenn, Profit from Pollution Prevention, Pollution Probe Foundation, Toronto, 1982.

6. Pollution Prevention Bibliography, North Carolina Department of Natural Resources and Community Development, Raleigh, NC., 1987.

7. Hazardous Waste Minimization Manual, Center for Hazardous Materials Research, University of Pittsburgh Applied Research Center, Pittsburgh, PA 15238.

8. B. Fleet, J. Kassirer, T. Sanger T. Burrell, B. Cardoza and C. Small, A Study of the Economic Factors Relating to the Implementation of Resource Recycling or Zero-Discharge Technologies for Heavy Metal Generating Industries in Canada, Project 316RR, Ontario Ministry of the Environment, 1987.

9. G.C.Cushnie, Jr., Electroplating Wastewater Pollution Control Technology, Noyes Publications, Reston, VA., 1985.

10. B.Piasecki (Ed)., Beyond Dumping: New Strategies for Controlling Toxic Contamination, Quorum Books, Westport, CT., 1984.

11. U.S. Congress, Office of Technology Assessment, J.Hirschorn (Ed)., Technologies and Management Strategies for Hazardous Waste Control, OTA-M-196, US Government Printing Office, Washington, DC.,1983.

12. J.Eason and R.DeBisschop, Pollution Control in the Electronics Industry, Metal Finishing, February, 1984, p.69-74.

13. D.M.Grosse, "A Review of Alternative Treatment Processes for Metal Bearing Waste Streams" in H.M.Englund, (Ed)., Treatment Technologies for Hazardous Wastes, APCA Publications, Pittsburgh, 1987.

14. T.Oppelt (Ed)., Performance and Costs of Alternatives to Land Disposal, APCA Publications, Pittsburgh, 1987.

15. B.Fleet, Electrochemical Reactor Systems for Metal Recovery and Pollution Control, Coll.Czech.Chem.Comm., 53,(6), 1988, pp1107-1133.

16. R.L.Judd, Jr., B.Fleet, C.E.Small, G.A.Davis, B.Piasecki and M.J.Mueller, Waste Reduction Strategies for the Printed Circuit Board Industry, California Department of Health Services, Contract #00173, Sacramento, CA, 1987.

17. Hazardous Waste Treatment Technologies, Government Institutes Inc, Washington, 1987.

18. B.Fleet in Ref 17, "Computer Controlled Integrated Chemical Waste Management Systems for the Electronics Products Industries", p XIII-1-19.

19. Mobile Treatment Technologies, Draft Report, Versar Inc., for EPA Contract # 68-01-7053, Cincinnati, OH 45268, 1986.

20. B.Piasecki and G.A.Davis (Eds), America's Future in Hazardous Wastes; Lessons from Europe, Quorum, New York, 1988.

21. G.E.Norgaard and G.Dodge, "Centralised Treatment and Recovery of Metal Finishing Wastes", Proceedings SURFIN Conference, Session Environmental N1, Amer.Electroplat. Surf. Finishers. July, 1987.

22. S.Schwartz, W.P.Cuckovich, N.S.Ostrom and C.F.Fox, Managing Hazardous Wastes Produced by Small Quantity Generators, for the Government of California, Senate Office of Research, 1987.

23. D.N.Dewees, C.K.Everson and W.A. Sims, Economic Analysis of Environmental Policies, University of Toronto Press, 1975

24. T.MacMillan, Federal Water Policy, Canada, Environment Canada, 1986.

25. D.Gibbons, The Economic Value of Water, Resources for the Future, Washington, 1986.

26. R.Swaroop and R.Carter, "Procedure to Assist Decision-makers in Selecting a Remedial Alternative for Hazardous Waste Sites" in G.Bennett and J.Bennett (Eds).,Superfund '87:Proceedings of the 8th National Conference, The Hazardous Materials Control Research Institute, Washington, 1987, p258-263.

27. C.A.Wentz, "Landfilling of Hazardous Wastes:The End of an Era", Environmental Progress, 694:N3;1987.

28. Environmental Pollution Control Alternatives; Economics of Wastewater Treatment Alternatives for the Metal Finishing Industry; USEPA, Technology Transfer Document, EPA 625/5-79-016, Cincinnati, OH., 1979.

29. Development Document for Effluent Limitations Guidelines and Standards for the Metal Finishing Point Source Category, USEPA., 440/1-83/091, Cincinnati, OH., 1983.

30. G.E.Walmet, B.Sanders, N.Schulta and A.Rahim, "Investigation of Energy Efficiency in the Electroplating Industry", New York State Energy Research and Development Authority, Albany, NY, Report 87-1 (1987).

31. Innovative and Alternative Technology Assessment Manual, EPA Office of Water Program Operations, EPA-430/9-78-009, Washington, 1980.

32. D.P.Duffy, G.E.Norgaard and J.Sandberg, "A Survey of Metal Finishing Wastewater Treatment Costs", Plating and Surface Finishing, April, 1987.

33. Technology Cost Estimates for the California List Land Disposal Restrictions; A Technical Background Document for EPA; Pope-Reid Associates, St.Paul, MN, 1987.

34. J.Tate, Recycling vs.Treatment and Disposal of Metallic Waste: a Comparison, P.C. Fab., May 1986, p 50-55.

35. S.Schwartz, D.R.Donegan, N.S.Ostrom T.Emmert and D.Sivas, Managing the Electronic Industry's Hazardous Wastes; Technology and Economics of Alternatives to Land Disposal, Report to California Legislature, Department of Health Services, 1985.

36. G.J.Pearson and S.R.Karrs, Plating and Surface Finishing, September 1986

37. "Case Study: Reclaiming Copper can be a Profitable Cash Crop", PC Fab., May 1984.

38. B.Fleet, C.E.Small, B.Cardoza nad G.Schore, "Case Study of a Fully Automated, Zero-Discharge Waste Management System for the Printed Circuit Board Industry", 73rd Annu.Tech.Conf.Proc.Am.Electroplat.Soc., Paper I-2, 1986.

39. B. Fleet, J. Kassirer, T. Sanger T. Burrell, B. Cardoza and C. Small, A Study of the Economic Factors Relating to the Implementation of Resource Recycling or Zero-Discharge Technologies for Heavy Metal Generating Industries in Canada, Project 316RR, Ontario Ministry of the Environment, Final Report, 1988.

E7

DETERMINANTS OF PARTICIPATION IN SOLID WASTE SOURCE-SEPARATION PROGRAMS IN HIGH-RISE APARTMENT BUILDINGS. Virginia W. Maclaren, Department of Geography, University of Toronto, Toronto, Ontario, M5S 1A1.

Recycling is an important waste management tool which has gained increasing momentum over the past several years in Ontario. To date, however, most residential recycling programs have been designed for low-rise housing only. The focus of this study is recycling in high-rise apartment buildings. The first step in the recovery of recyclables from the waste stream in apartment buildings is source-separation. The term source-separation, as used in this paper, refers to the separation of certain materials from the regular solid waste stream by apartment building residents. In a high-rise building, these materials may be returned to the building's unseparated waste stream or they may be kept separate and recycled.

This paper reports on the results of a survey of 328 apartment buildings in the City of Toronto which found that just under half of the buildings have source-separation programs. The most popular source-separation programs are for newspaper and glass (34%), glass alone (16%), newspaper alone (12%), and for the combination of newspaper, glass, and tin/steel cans (12%).

The main reasons why residents are being asked to separate their wastes include: recycling; prevention of damage to waste management equipment in the building; prevention of fire and safety hazards; and reduction of noise from disposal of unseparated waste down chutes. Excluding apartment buildings participating in the City of Toronto's recycling pilot-project, the study found that approximately 12% of the buildings with source-separation programs

recycle the separated materials. The remainder return the separated materials to the unseparated waste stream before collection by the municipality or other agency.

The diversity of waste management systems found in apartment buildings is one of the important barriers inhibiting fuller implementation of apartment recycling programs. The study identified twelve different waste management systems among the buildings surveyed. It also identified the types of source-separation systems being used. Most (82.3%) of the existing source-separation programs have convenient separation systems, meaning that residents take their separated wastes to the same location where they leave their unseparated wastes.

Most source-separation programs now operating have high levels of compliance by residents. For all materials, with the exception of spray cans, the building managers/superintendents felt that the majority of residents were complying with their request to separate. Failure to achieve full compliance with the separation policy was attributed to four factors: (1) residents are aware of the policy but are unwilling to cooperate; (2) residents are now aware of the policy or have forgotten about it; (3) residents are too old or feeble to participate; and (4) residents are not aware of the policy because of a language barrier.

When asked what problems they foresaw in initiating recycling programs in their buildings, superintendents and managers cited many of the same problems identified above for compliance with existing source-separation programs. They felt that the three most important problems would be: tenant apathy

(53%), extra work for building staff (45%), and storage constraints (43%). Other problems mentioned included: (1) extra cost for the owner; (2) elderly residents will not be able to cope; (3) storage of separated materials may be a fire or health hazard; (4) residents must be educated about the need to participate; and (5) a language barrier may be a problem for education programs.

The last phase of the study was to develop a decision model that would identify variables which affect management's decision to initiate a source-separation program. This model could then be used to estimate the number of buildings in an urban area that might be expected to have separation programs. The results of fitting a logit model to the apartment data indicated that type of ownership and presence of an incinerator were both statistically significant variables for explaining the decision to separate. The type of building which is most likely to have a source-separation program has condominium or cooperative ownership and has an incinerator. In fact, these buildings are about 11 times more likely to have a separation program than not to have one. Buildings with individual or public ownership and no incinerator are the least likely to have separation programs.

In Ontario, the influence of incinerators on the decision to separate is especially important. The operation of incinerators in apartment buildings will be banned as of May, 1989, because of concerns about air pollution. Just under half (43%) of the 53 buildings in the data set with incinerators were found to have switched to alternative waste disposal methods. In many cases, this switch was also accompanied by the elimination of existing source-separation programs. This result implies that, in Ontario at least, recycling programs

should be initiated in apartment buildings with operating incinerators before the incinerators and source-separation programs are phased out and residents of these buildings grow out of the habit of separating their waste.

To conclude, the findings of this study indicate that establishment of recycling programs in high-rise apartment buildings will not require significant behavioural changes by a large proportion of apartment building residents and staff because they are already participating in source-separation programs. Although I do not discount the effort that will have to go into obtaining resident, staff, and management cooperation in the establishment of recycling programs, I believe that the most serious barriers may be physical in nature. These include: lack of storage space for recycling containers, lack of access for collection vehicles, and the general complexity of waste management systems in apartment buildings. The implication of the complexity problem is that implementation of apartment building recycling programs will most likely require that program managers make site visits to all buildings, prior to initiation of the program, in order to customize a building's recycling system. Clearly, establishment of recycling programs in apartment buildings will be labour-intensive and time-consuming, but the necessity for careful site inspections may result in the discovery that managers and superintendents contacted in this study have over-estimated the difficulties of storage and access.

E8

THE ONTARIO ENVIRONMENTAL PROTECTION INDUSTRY AND THE IMPACT OF ENVIRONMENTAL EXPENDITURES ON THE ONTARIO ECONOMY

by

Lee M. Coplan
Policy and Planning Branch
Ontario Ministry of the Environment
Toronto, Ontario

and

Avery B. Shenfeld
Woods Gordon Management Consultants
Toronto, Ontario

To be presented at the Technology Transfer Conference
November 28, 1988

October, 1988

ABSTRACT

An overview of the current economic activity generated in Ontario as a result of environmental regulations is presented along with the prospects for economic growth of this industry and the perceived impact of free trade on these prospects. Responses from surveys of both users and suppliers of environmental protection goods and services are described. Approximately 28,000 are employed in Ontario in the generation of about $2 billion in annual sales of Ontario-produced environmental protection products and services. Growth in this industry has been strong during the past five years, and the growth prospects for the next five years seem quite favourable.

An environmental protection impact model (EPIM) is employed to project the potential impact on the Ontario economy of potential changes in environmental regulations. Offsetting the economic impact of additional costs imposed by more stringent regulations is the gain of jobs and production of goods and services in the environmental protection industry and among suppliers to this industry.

1. INTRODUCTION

In developing and defending its policies, the Ontario Ministry of the Environment is often called upon to evaluate the economic implications for the province arising from environmental regulatory changes. A comprehensive assessment of possible changes in environmental regulations requires a determination of both the likely incremental costs and the potential benefits that would result from the changes. Distributional effects are an important consideration, and care must be taken so that true economic consequences are measured.

Additional costs incurred by some segments of the economy so as to improve environmental quality will generally result in benefits for other segments. The direct benefits to others that arise through reducing emissions of pollutants into the environment are termed "externalities." While firms in the environmental protection industry can be expected to profit from more stringent regulatory standards, their gains from additional environmental protection activity constitute a "transfer" from the purchasers to the suppliers of such goods and services. Failure to account adequately for such external benefits (alternatively, reductions in external costs) or transfers of economic activity in any analysis tends to stack the deck against more stringent regulatory standards. Potential cost increases are less likely to go unnoticed.

Many of the external benefits arising from pollution abatement are quite diffuse. As a consequence of a particular environmental initiative, the economic value to most individuals of improved health (or reduced risk of disease), of additional building longevity, of reductions in aesthetic impairment, etc., may be rather low. Nevertheless, by adding up the individual gains, the total benefit to the economy may be substantial.

In other instances, individual external benefits may be substantial. More stringent abatement measures required of an upstream polluter may reduce the cost of water filtration and purification downstream. In addition, the health and aesthetic impact of pollution, among its other effects, may be substantial

for those who live or work near the source. Consequently, higher costs imposed on one firm may reduce costs to other firms and households. This example could be stated just as forcefully for benefits arising from more stringent air pollution standards.

As for the transfer effects of regulatory change, additional expenditures by one Ontario firm may provide revenues to another. (The expenditures may "leak" to firms outside of the province.) Firms which provide pollution control equipment or services are likely to gain business and become more profitable as a result of the additional costs arising from the regulatory change.

Environmental regulations in Ontario are the cause of a sizeable amount of economic activity in the province through the provision of pollution control equipment, materials and services. This activity represents a transfer of economic activity from other sectors of the economy, since the need to devote investment funds to meeting environmental regulatory requirements may lower rates of return and thereby reduce industrial investment spending. A constraint on funds for capital expenditures implies that, in the short run, investment in environmental protection equipment will prevent investment in productive capacity that would otherwise take place.

The production of pollution control equipment and services generates additional activity, or spinoffs, in the economy. This comes about both from the purchases of machinery and materials by the environmental protection industry and from the consumer spending generated as the result of salary and wage payments to employees in the industry.

The focus of this paper is on the economic spinoffs, or transfers, resulting from environmental protection expenditures. The effect of control orders and regulatory changes on the environmental protection industry are relatively easy to generalize. The analysis of benefits generally must be carried out on a case by case basis.

This paper provides an overview of the environmental protection industry in Ontario. The discussion which follows is based on a recently completed study which was carried out by Woods Gordon Management Consultants (1988) for the Ministry of the Environment. This study assesses the scope and scale of environmental protection activity in Ontario and provides a model of the economic impact of such activity. It follows up work initiate in an earlier study, aimed at defining the industry, which was carried out by Institute for Research on Public Policy (1987) for the Ministry of the Environment.

The following section of this paper briefly defines the environmental protection industry and discusses the methodology used to gauge the extent of environmental protection activity in Ontario. Surveys of purchasers and suppliers of environmental protection equipment and services are described. Estimates are provided of revenues earned by various segments of the Ontario environmental protection industry and of the direct employment by this industry. Growth prospects for the sector, and the likely implications of the Free Trade Agreement on these prospects, are discussed. Finally, industry views on the role of the Ontario government in stimulating further growth are presented.

The third section of the paper describes the Environmental Protection Impact Model (EPIM) which was developed as part of the Woods Gordon study. Derived from an input-output model, the EPIM is a tool that can be used to evaluate particular effects of potential changes in environmental regulations. This model takes into account the economic transfers and spinoff effects mentioned above, but not the external benefits of abatement and control activities. The response of individual firms or sectors to potential regulatory changes in their decisions as to levels of production, employment and investment can be used as an input into the model, but this model does not generate a forecast of such responses by firms. To provide a more concrete example of both the appropriate use and the limitations of EPIM, the model is used to analyze the potential impact of a rather stylized

version of a possible change in regulatory requirements affecting air pollution.

2. THE ONTARIO ENVIRONMENTAL PROTECTION INDUSTRY

2.1 Defining the Industry

Environmental protection activities are those designed to reduce or avoid emissions of materials that are detrimental to the environment. The environmental protection industry includes suppliers of equipment and services for air pollution control, wastewater treatment, solid and hazardous waste disposal and recycling, and monitoring and analyzing environmental data. The environmental protection industry definition was defined in the Woods Gordon study to include private sector Ontario manufacturers or service suppliers of specialized environmental protection goods and services, and the construction involved in equipment installation, as well as engineers and other consultants who provide advisory services on environmental protection matters.

Products which have a variety of industrial uses including environmental protection activities are included in the economic impact model but not in the discussions of the scale and trends in the environmental protection industry. Pipes, valves and wiring used to connect and install pollution control equipment are examples of such products. Also excluded from the study of the environmental protection industry are resource conservation, nuclear waste management and noise abatement activities. Nor was there any attempt to measure the direct employment or value of services provided by environmental protection personnel at government environment departments or public utilities.

2.2 Data Sources

No comprehensive data source exists for the environmental protection industry in Ontario. Most of the activity in this sector is undertaken by firms involved in a range of non-environmental manufacturing and service activities, and is

therefore incorporated into broader industry categories by statistical agencies. Data on expenditures on environmental protection (as opposed to Ontario production of environmental protection products and services) are available in an incomplete form, with public sector spending tracked more comprehensively than private spending.

It was necessary, for the purposes of the study, to undertake for the first time a significant effort at obtaining new quantitative and qualitative perspectives on this sector in Ontario. These data were obtained by four different approaches:

(1) a review of existing literature and statistical sources;
(2) interviews with 75 purchasers of environmental protection products/services;
(3) a mail survey sent to over 1,800 Ontario firms identified as possible manufacturers of goods or suppliers of services for environmental protection; and
(4) follow-up interviews with 30 suppliers of environmental protection products.

The interview samples were drawn from a wide range of purchasing industries and municipalities, and from suppliers of various products and services for air, water and solid and hazardous waste pollution control.

The literature review covered both published and unpublished reports on the environmental protection industry in Ontario, in Canada as a whole and in other countries. A very large body of literature is available on very specific aspects of environmental protection engineering and technology. The focus, however, was on the somewhat smaller group of reports on the economic aspects of the environmental protection industry and the scale of activity in various jurisdictions.

Data are also available from Statistics Canada on capital expenditures for which firms claimed accelerated capital consumption allowances under tax law provisions allowing special

treatment for water and air pollution control assets. Officials in the relevant department of Statistics Canada indicated that data obtained by this method would provide a misleading picture of actual pollution control expenditures. Similarly, officials at the Approvals Branch of Environment Ontario advised that many firms do not report project costs on their applications for certificates of approval, so that these data would seriously understate the potential expenditures.

The survey of purchasers was intended to provide an indication of the types of products and services demanded, the role that Ontario firms play in meeting the needs of these purchasers, the views of purchasers as to the future growth in their environmental protection spending, and the impact of bilateral free trade on the Ontario environmental protection industry.

In order to obtain a broad-brush view of the activity of environmental protection firms in Ontario, a large-sample mail survey of Ontario environmental protection goods and service suppliers was carried out in the spring of 1988. The purpose of the survey was to obtain an indication of the scale of the industry in the province, and employment levels, recent growth trends and future growth possibilities, and product range within the industry. In contrast to the existing work that has been directed at estimating the value of environmental protection goods and services *purchased*, the emphasis in this part of the study was on the even more difficult task of obtaining data on the nature of environmental protection industry *production* with significant Ontario content.

2.3 Supplier Survey Procedures and Responses

The list of respondents was initially compiled from a directory of environmental protection firms in Canada which was assembled by William Glenn (1987a). Over 1,700 Ontario firms were listed. Because the number of Ontario firms in the list identified as manufacturers of the air pollution control equipment appeared to be too low, firms identified as part of

this sector were added. The survey was sent to over 1,800 firms. A portion of these firms turned out to be distributors rather than manufacturers of environmental protection products, or to be selling products and services that were only tangentially or infrequently related to environmental protection applications. Consequently, the universe of domestic manufacturers of reasonably specialized environmental protection goods or service firms is judged to be on the order of 1,200 firms.

A total of 261 firms responded to this survey, a 14% rate of response. Of these, 197 indicated that they were involved in environmental protection activities in Ontario. Of this group, 164 provided sales and/or employment data. A total of 138 provided sales and employment data, 21 provided employment data but no sales data, and 5 provided sales data but no employment data. The other 33 firms supplied some data on products and growth projections, but did not report sales or employment. Some 64 firms indicated that they were not, in fact, involved in environmental protection manufacturing or services in Ontario. The list of firms with complete responses includes many of the largest firms in the Ontario environmental protection industry and a large number of small service sector firms.

The respondents to the supplier survey sold over $0.5 billion in Ontario-produced environmental protection products and services in 1987. These sales figures are generated by firms producing products and services with a high degree of Ontario content. Only 10 firms, primarily instrument manufacturers, reported less than 50% Ontario content in their Ontario-made products. This is not surprising, since services account for a significant share of the total environmental protection production in the province, and the survey excluded distributors of imported products. Since any voluntary survey will achieve only a partial response rate, the survey findings reported here provide an initial lower-bound for the scale of the industry in Ontario.

The total sales of environmental protection goods and services in the province is likely to be much higher than the figures generated in our sample of respondents. A number of other statistical sources were reviewed in an effort to obtain an understanding of the full extent of environmental protection activity in the province. Necessarily rough estimates of the annual sales volume of the Ontario environmental protection industry by major category have been prepared. Such estimates are based on these other sources, together with survey responses, a review of the list of respondents and non-respondents in light of knowledge about the leading industry participants, and discussions with over 100 industry participants. These estimates should be viewed as conservative (i.e., low) ranges for the magnitude of the various types of environmental protection activity in Ontario. They provide a useful indicator of the importance of the overall environmental protection sector to the provincial economy.

2.4 Characteristics of the Industry

As shown in Table 1 below, the size of the environmental protection industry in the province appears to be on the order of $1.5 to $2.5 billion in terms of total annual sales revenue, excluding non-specialized goods and services used in conjunction with environmental protection products.[1] Within these totals, wastewater treatment accounts for the largest share of the goods production sector, while solid and hazardous waste disposal and recycling are the largest service sector contributors. In addition to these commercially provided goods and services, all three levels of government provide a range of environmental protection services.[2]

---

[1] For the purposes of determining the scale of and trends in the Ontario environmental protection industry, products which have a variety of industrial uses apart from environmental protection activities were excluded. See Section 2.1 above.

[2] The following studies give an indication of the extent to which expenditures by the three levels of government contribute to estimated industry sales revenues as reported in Table 1.

Table 1
ESTIMATED 1987 REVENUES OF THE ONTARIO ENVIRONMENTAL PROTECTION SECTOR*

Commodity	Estimated 1987 Revenues
Machinery, Equipment, Instruments, Supplies	$250 - $400 million
Recycling Services	$500 - $1,000 million
Waste Disposal and Destruction Services	$300 - $400 million
Construction Services	$350 - $500 million
Consulting Engineering and Analytical Services	$100 - $200 million
TOTAL	**$1.5 to $2.5 billion**

* Excludes services provided directly by governments

Corporate Policy and Planning (1986) reports a total value of Ontario government expenditures on environmental protection of $912 million in fiscal year 1983/84. Some, but not all, of such expenditures for 1987 would be included as environmental protection industry revenues in Table 1 above. An examination of preliminary figures for Ontario public sector expenditures on environmental protection through 1987 suggests that such expenditures account for more than 50% of industry revenues.

According to Laikin and Donnan (1987) in their study of environmental protection expenditures in Canada, over 70% of capital expenditures for environmental projects during the period from 1980 to 1984 were incurred by the public sector. Private sector figures for operating and maintenance costs related to environmental protection could not be determined. Total expenditures on environmental protection and pollution by all levels of government in Canada averaged $5.1 billion during the 1980 to 1984 period, of which $3.4 billion (67%) were public sector operating and maintenance expenditures.

The 159 firms that responded with employment data in the mail survey were responsible for the direct employment in Ontario of 5,455 person-years in their environmental protection operations. Total employment in the environmental protection industry is therefore considerably greater.

An estimate of total industry employment can be derived from the ratio of employment to shipments indicated in the survey, the typical level of construction expenditures to construction industry employment, the ratio of employment to shipments of members of the Canadian Association of Recycling Industries, and the estimate of total industry sales revenue above. Based on these factors, it is estimated that the environmental protection industry generates direct employment in Ontario of 20,000 to 36,000 full-time equivalent positions.

As indicated by Table 2 below, total Ontario employment in the environmental protection industry is comparable to that in the communications equipment, clothing and wood products industries, and ahead of such industries as metal mining. The 5,455 employees identified in our mail survey alone would put the environmental protection sector close to or ahead of such industries as Shoe Factories (7,500 employees in June, 1987), Knitting Mills (6,500), Iron Foundries (5,200), and Major Appliances (5,100).

The total number employed in all environmental protection related activities in Ontario is much larger. Federal, provincial and municipal officials involved in environmental activities and environmental engineers at large industrial plants, and at firms manufacturing pipes, wires and other basic products used in conjunction with environmental protection industry products should also be counted. Glenn (1987b) estimated that across Canada, governments employed over 50,000 individuals in environmentally-related positions. If employees of non-specialized equipment producers were included, he estimated that environmental protection employment in Canada could be as much as 150,000. Laikin and Donnan (1987) reported

that total employment directly related to environmental protection was at least 100,000 in Canada during the period from 1980 to 1984. They also indicate that total employment in environmental activities by the three levels of government was 43,000 people during this period.

Table 2
ENVIRONMENTAL PROTECTION INDUSTRY EMPLOYMENT IN ONTARIO RELATIVE TO OTHER SELECTED INDUSTRIES, 1987

Industry	Ontario Employment
Rubber and Plastic Products	48,100
Paper and Allied Industries	43,400
Furniture and Fixtures	34,800
Communications Equipment	30,000
Environmental Protection	**28,000 (est.)**
Clothing Industry	27,400
Wood Industries	27,100
Metal Mines	19,700
Pharmaceuticals and Medicines	10,300

Source: Statistics Canada (72-002) data for June, 1987 and Woods Gordon estimate

2.5 Industry Growth

The results of the mail survey indicate that sales of industry participants have been growing quite strongly since 1983, particularly for firms in the air and water pollution control sectors. Those firms reporting environmental protection sales in 1983 showed a compound annual growth rate ranging from 17% in solid and hazardous wastes to 32% in wastewater treatment over 1983-87.

It should also be remembered, however, that the Ontario economy was emerging from a recession in 1983, in which capital expenditures for all items had fallen off dramatically. Thus the reported growth rates from that period may exceed sustainable, longer term prospects. In addition, the data may themselves overstate actual total industry growth over the 1983-87 period. Evidence from the growth of public expenditures on environmental protection activities shows a somewhat more modest growth rate for their share[3] of environmental protection spending.

Both purchasers and suppliers of environmental protection products and services anticipate rapid growth in sales over the next five years. Among the suppliers who responded to the mail survey, the weighted average annual growth rate expected for the next five years (with the weights based on each firm's share of total 1987 sales) was 17% per year, more than twice the growth rate generally anticipated for nominal gross domestic product (GDP) in Ontario. While these expectations may reflect an overly optimistic assessment by individual respondents on the share of the market their firm will achieve, it appears that there is a general consensus that environmental protection will be a rapidly growing field into the 1990's.

Most of the sales increase anticipated by environmental protection suppliers are based upon their belief that environmental protection legislation will be significantly tightened in Ontario and elsewhere in Canada over the next few years. Purchasers generally appear to share this viewpoint.

The mail survey and interviews with selected industry participants suggest that strong growth opportunities exist in all three major segments of the environmental protection industry

---

[3] Preliminary Environment Ontario figures for the period from 1980 to 1985 suggest an average growth rate of 5.6% for Ontario public sector expenditures which flow directly to the private sector. See note [1] for a discussion of the public sector's share of total environmental protection spending.

(air, wastewater and solid and hazardous waste). Near term opportunities will include the supply of goods and services related to meeting the needs of such purchasers as Ontario Hydro and others responding to tightened provincial regulations. There are important requirements for monitoring equipment and analytical services designed to meet the new emphasis on monitoring and controlling emissions of toxic substances in low concentrations. In the longer term, solutions to the growing problems associated with solid and hazardous waste disposal could provide opportunities for recycling services and various process innovations designed to reduce waste production at the source.

2.6 International Competitiveness and the Impact of the Free Trade Agreement

Of the respondents reporting sales data, 66 firms indicated that some or all of their 1987 revenues were attributable to export sales. These firms registered total export sales of $67.8 million last year, or 13.5% of the total value they reported of environmental protection production in the province. It is not possible, however, to confirm whether or not this export share is typical for the industry, as most environmental protection commodities are included in broader export figures in Statistics Canada data.

The future of the environmental protection industry in the province will depend on the ability of firms in Ontario to compete with equipment and service suppliers from the United States, and to a lesser extent, Europe and the Far East. In the goods sector, Ontario firms already compete with imports, particularly in the fields of instrumentation and basic equipment (pumps, motors and other machinery) used in environmental protection. In the service sector, much of the activity in the province is handled by employees from local offices, regardless of whether their employer is based in Ontario, elsewhere in Canada or is a local branch of a multinational.

Study findings suggest that free trade will be modestly beneficial to the Ontario environmental protection industry,

despite the fact that existing trade barriers are higher on U.S. exports to Canada than on Canadian exports to the United States. Freight costs and custom design requirements will continue to limit the extent to which the final assembly of environmental protection products could be centralized outside the province. Ontario service sector firms are quite competitive, and could expand the export of consulting engineering and design services. In the supply of higher-technology pollution control devices, Ontario firms are competitive in certain product niches, while other such products are already largely imported.

There was a broad concern that exchange rates were at least as important as tariffs in determining Ontario's trade balance in the environmental protection sector. Many respondents suggested that their competitive position would be eroded if the Canadian dollar went much above $0.80 U.S. in the absence of other competitive-enhancing developments, such as more moderate wage rate inflation in Canada than in the United States, or improvements in the relative productivity of labour in Canada.

Some of the other factors affecting the Canadian environmental protection trade balance will not be addressed by the Free-Trade Agreement. The perceived lack of awareness among Canadian engineering consultants about Canadian supply capabilities, and the resulting frequency with which they direct business to foreign suppliers in their specifications, was mentioned by Canadian manufacturers of water treatment equipment (and other environmental protection products) as being a trade irritant. Also mentioned as a trade irritant is the "Buy America" legislation in the United States which requires that state and local projects which receive federal funding must provide a price preference for domestic suppliers over foreign bidders, and which will be allowed to continue.[4]

---

[4] A similar provision in procedures for evaluating bids for public projects in Canada gives a cost advantage based on the Canadian content.

2.7 Industry Concerns and the Role of Government

In addition to the issues raised in the course of the review of the environmental protection industry's growth prospects and competitiveness, both purchasers and suppliers in the Ontario market were asked to identify areas of concern. In general, officials with the major industries which are subject to environmental regulations remain uncertain as to the ultimate implications of the trend towards tighter regulatory requirements in Ontario. Beyond the need for improved monitoring of effluents, industry engineering personnel felt little could be said until the actual abatement requirements are defined under the *Municipal/Industrial Strategy for Abatement (MISA)* and the *Clean Air Program (CAP)*.[5]

In particular, while industry officials are aware that the adoption of the Best Available Technology Economically Achievable (BATEA) will be required, what these requirements will be in practice is still unclear. If the requirements dictate no more than what is currently required in the United States, there should be no major technological difficulties. Otherwise, the prevailing view is that long lead times will be necessary in order to implement the new standards without imposing a substantial financial burden on Ontario industry.

Most suppliers felt confident that they could meet many of the technical requirements arising from the new regulatory requirements, as they expect that the ultimate regulations will not require industries and municipalities to exceed the standards already in place, if not always enforced, in the United States. Ontario, in turn is viewed as setting the stage for parallel legislation in other provinces. Many suppliers feel that industries could retrofit and clean up processes to meet legislated targets, and that this need not involve the large dollar figures which the affected industries will inevitably claim.

---

[5] See Ontario Ministry of the Environment, 1987a and 1987b.

Following the American lead was thought by some to be detrimental to the environmental protection industry in Ontario. By taking the lead in regulatory requirements, if not in enforcement, the U.S. stimulates its firms to develop technologies which can then be exported. In some fields of pollution control, the U.S. is viewed as being five years ahead of Ontario. When compared with the views of purchasers, it appears that the most beneficial approach for both suppliers and purchasers involves being at the leading edge in terms of announcing future targets for environmental protection, but allowing sufficient lead times before new standards come into effect to allow for the design and development of appropriate technologies in Ontario.

Both the approvals process administered by Environment Ontario and the design specifications made by consulting engineers are perceived by environmental protection equipment suppliers to promote the use of existing U.S. technologies in Canada rather than foster the development of new environmental protection technologies in Ontario. Some firms felt that, although control orders and environmental regulations mention only end-use performance, in practice approvals are granted on the basis of meeting design requirements. An unverified perception of suppliers is that new pilot projects which are being tried in the U.S. would not be approved in Ontario.

Thus, while encouraging research on the one hand, the Ministry is viewed by suppliers as promoting the conservative use of existing technologies through its approvals process (by favouring the adoption of old technologies over experimental systems), and by lagging behind the U.S. in promulgating new regulatory requirements. A similar conclusion was reached by the Task Force on Environmental Protection Technologies (1983). Consulting engineers also promote this conservatism, according to equipment manufacturers, by specifying existing technologies and resisting innovative Ontario equipment that has not been applied elsewhere. Similarly, engineers at multinationals tend

to copy designs used in parent company plants, reinforcing the use of imported equipment.

A problem that was mentioned by a few respondents concerned the lack of attention given to Canadian content by Ontario municipalities. It was suggested that price-advantage policies comparable to the "Buy America" program in the United States would help would help domestic manufacturers and would bring tendering practices of Ontario municipalities in line with those of the United States and other countries.[6] Others suggested that municipalities should be given less latitude by the Ministry, since what they view as lax standards have sometimes led municipalities to adopt low-cost, but ineffective equipment to the detriment of suppliers of more effective, but more expensive, technologies.

There is considerable government involvement in many of the "high tech" aspects of solid and hazardous waste disposal.[7] Individual departments within the federal government are responsible for environmental assessment and maintenance of federal lands, with Environment Canada having the mandate to establish general guidelines and standards. Provincial governments are responsible for provincial lands, and each province is establishing guidelines and legislation. The

---

6 Ontario municipalities are, in fact, subject to provincial guidelines that provide a 10% price advantage based on the Canadian content of tenders for the purpose of comparing bids. While there may be municipalities that fail to carry out these guidelines on all bids, the problem may be primarily one of perceptions. The municipality of Metropolitan Toronto, for example, indicates that it has adhered to these guidelines on all tenders during the past ten years.

7 Possible examples include government actions which encourage or regulate new technology for the disposal of toxic waste. Capability for the destruction of PCB's and other highly toxic wastes has been developed in Ontario. The expertise exists in the province to manufacture plasma arc furnaces capable of achieving the temperature and resident time necessary to burn and break up organic chemicals. See Woods Gordon (1988), page 58.

environmental assessment personnel and chemists who were consulted felt that it was very difficult to "nail down" the provincial ministries regarding what are and are not acceptable technologies and procedures in the area of hazardous waste disposal. The provincial ministries, on the other hand, have to receive public input into the establishment of standards and guidelines, and this is proving to be a time consuming process. As a result, highly feared chemicals such as PCB's have yet to be destroyed in Canada and they continue to accumulate and be stored on a temporary basis.

In terms of direct government assistance to the environmental protection industry, participants felt that this was of secondary importance to the timely development and enforcement of environmental legislation. Grants and research funding cannot have the impact that will be produced by environmental protection legislation, by tougher fines placed on violators, and by ensuring that enforcement is not a cyclical phenomenon that is neglected each time there is a business slowdown. However, a number of firms had already participated in existing federal and provincial programs for research and development, and there was a fairly broad-based support for a greater Ontario government role in the development of new environmental protection goods and services in the province.

According to one respondent, a successful Ontario manufacturer of instrumentation, the Trade Export Fund (of the Ministry of Industry, Trade and Technology), the Export Manager for Hire program, and the College Intern program were all very useful and of great value. Others cited the federal government's IRAP program as being particularly effective. However, these programs were felt to be small relative to the kind of push to the industry provided by the American Superfund program.

Research and development assistance appears to be more of a concern in select, high technology components of the environmental protection industry. Most of the foreign-owned companies contacted have very little research and development

capability in Ontario, though occasional product improvements are not unusual. Coupled with the absence of a mandate to export for these branch plants, this feature of branch plant operations in the environmental protection sectors is thought to be a factor limiting the potential success of government policies designed to promote Ontario exports from these multinationals. By taking the lead in developing environmental standards and regulations, the government might be in a better position to use other incentives to encourage multinationals to undertake research and product development in Ontario, rather than following the lead of their parent companies who have already reacted to earlier U.S. regulations. The export performance of domestically-based firms might also be similarly enhanced.

3. THE IMPACT OF ENVIRONMENTAL PROTECTION EXPENDITURES ON THE ONTARIO ECONOMY

3.1 Characteristics of the Environmental Protection Impact Model

The Environmental Protection Impact Model (EPIM) is a tool developed for the Ministry of the Environment to help derive estimates of the economic impact of potential changes in environmental regulations. The impacts are in the form of jobs and income generated in Ontario through the supply of environmental protection products, both directly and indirectly through the effect of the resulting spinoffs. The economic impact of environmental protection activities and the direct benefits of an improved environment resulting from tighter regulations can be weighed against their estimated economic costs to the province.

The estimates obtained using the EPIM should be viewed as rough approximations for the actual economic impacts of environmental protection spending from regulatory change. The actual required expenditures can only be approximated before the regulation comes into force. The spinoff effects captured in this model, or any other, are approximations of those which would actually take place. Finally, as noted in the introduction, the

response of individual firms to regulatory change in their choices of production, employment and investment levels must be determined exogenously, and the external benefits to other firms are ignored by the EPIM.

The EPIM is based on multipliers derived from Statistics Canada's *Interprovincial Input-Output Model*. Multipliers are coefficients which relate expenditures on one commodity to their total impact on the economy. Input-output modelling is a special case of general equilibrium analysis which attempts to model all of the linkages between the various sectors of the economy. Changes in the output of one commodity will, in a general equilibrium model, result in changes in demand for labour and for the various commodities that serve as inputs into the production of that commodity. The resulting changes in input use require further adjustment in the levels of labour and other commodities used in their production.

In input-output analysis, the relationship between the various commodities is assumed to be linear and fixed. Production of each product is assumed to require a constant mix of inputs from the various sectors of the economy, regardless of the level of output. Conclusions derived from input-output models are reliable so long as relatively small changes in output and relatively short time periods are considered. Input-output models, because of their linearity, may be more sensitive to such caveats than more general models to which they also apply.

It is also assumed that there is unemployment and excess productive capacity in the economy, so that suitable resources exist to meet any increase in demand. The possibility of labour shortages or capacity constraints is excluded in this type of model. As is the case with more general models of this type, the predictions of an input-output model would be suspect when various sectors are operating at close to capacity.

The EPIM has separate multipliers for 92 different classes of commodities. The model is able to estimate the economic

impact in Ontario of each dollar spent on any of the 92 commodity classes, including the spinoff effects on labour and required inputs. There are separate multipliers to capture the effect of changes in direct employment. For expenditures that are known to be made in Ontario, the commodity classes are consolidated into 43 groups.[8] Multipliers are higher for commodities for which Ontario production constitutes a greater share.

Use of the model requires estimates of the incremental expenditure, by commodity class, generated by the proposed regulatory change. In addition to the change in environmental protection expenditures resulting from the regulatory change, a complete analysis would include the differences in investment and in input requirements which constitute firms' responses to the new regulations. The EPIM translates these estimates, broken down into repeat and one-time expenditures, into estimates of permanent and one-time employment and GDP impacts.

To the extent that multipliers differ for the various commodities, more accurate estimates of economic impact can be achieved when environmental protection expenditures are allocated accurately among the commodity classes. This exercise can be quite challenging. Firms often have substantial latitude in their choice of abatement measures to achieve regulatory objectives. In addition, abatement expenditures usually involve allocations to several commodity classes.

While care should be taken in classifying expenditures, some experience with the model indicates that, in general, choices made between similar categories will not appreciably alter the order of magnitude of the impact estimates. The EPIM is intended

---

[8] See chapter 7 of Woods Gordon Management Consultants (1988), for a list of commodity classes used in the model and examples of environmental protection goods and services in various of the classes. This source also describes the EPIM in greater detail than is possible in this paper. Appendix II of Woods Gordon provides a complete printout of an illustrative example run through the EPIM.

to provide an indication of the range of possible employment and income consequences of a project or regulatory change rather than a precise point estimate.

3.2 Use of the Model: An Example

To give a better idea of the appropriate use of the EPIM, the model was applied to provide the economic impacts resulting from costs estimates of a possible regulatory change. The Ontario Ministry of the Environment (1987b) has proposed several important revisions to Regulation 308 (General Air Pollution) of the Environmental Protection Act. If adopted, direct emission limits would be imposed on all air pollution sources of an appreciable size, and the existing air quality criteria would be replaced by ambient air standards. Other changes from the existing regulation were also proposed.

To assist in deliberations about the proposed revisions to Regulation 308, the Ministry commissioned an economic assessment to examine the likely benefits, costs and consequences of implementing the proposals. The actual benefits, costs and consequences of the proposed revisions will depend on what emissions standards are actually put into place. Approximations of possible standards were used to derive a variety of implementation scenarios. Several of these scenarios are evaluated in the economic assessment so as to provide a range of options that will be useful for deciding how best to implement the proposed revisions. The details and results of the economic assessment are to be reported in VHB Research and Consulting Inc. (forthcoming).

Because the proposed revisions to Regulation 308 are still in the discussion stage, the anticipated benefits and costs that would result are as yet uncertain. Taking projected expenditures for additional monitoring and abatement for one of the scenarios studied in the economic assessment as inputs, the EPIM is used to derive the impact of this aspect of the proposed revisions on the Ontario economy. That a particular scenario is analyzed in this paper rather than any of the others does not in any way

suggest that it is preferred by Environment Ontario or that it dominates the others on a basis of the economic assessment. This exercise is intended only as an illustration of the EPIM.

The economic assessment describes a variety of abatement and monitoring technologies that are likely to be employed in response to implementation of the proposed revisions to Regulation 308. Among the types of air pollution control equipment now in use in Ontario and for which demand is likely to increase are the following:

Baghouses - systems to trap particulate matter in which the emissions are forced through a chamber containing cloth bags. Among their components are valves, iron walls, temperature sensors, and flow measurement devices.

Cyclones - a type of inertial separator which causes heavier particles to settle by swirling gases using fans or a spinner. Inertial separators are used primarily for collecting medium- and coarse-sized particulate matter.

Electrostatic Precipitators - devices designed to collect particulate matter out of gases through the use of electrically-charged rods. They contain some electronic components, but are not a very high-technology product.

Incinerators (Afterburners) - devices used to burn off waste gases including combustible aerosols, particulates, gases or vapour emissions. (Incinerators used to burn solid or liquid waste are *users* of air pollution control equipment.)

Scrubbers (Gas absorption) - systems which remove one or more constituents from a gas stream by dissolving them in a selective liquid solvent. They are composed of spray nozzles, jets of water, lime, a steel box, valves, a water pump, flaps, temperature controls and pressure sensor instrumentation, or variations on the above. They are not very high-technology products.

Additional monitoring equipment will also be required to ensure that the mandated abatement levels are achieved. Several types of monitoring needs will have to be satisfied, as indicated below:

Continuous Emission Monitoring Systems (CEMS) - devices that give a series of on-line measurements of the concentration of specific components that may be contained in a gaseous effluent. The particular definition of "continuous" (that is, the frequency of sampling) influences the characteristics of the type of monitor that must be employed in any given circumstances. Such devices will be used as compliance monitors.

Stack Sampling - a variety of techniques used to measure the emissions, including rate and concentration, from a stationary source. Systems are available for emissions of particulate matter, organic compounds, sulphur dioxide, nitrogen oxides, total hydrocarbons and other pollutants.

Ambient Air Quality Monitoring - required to ensure that ambient air standards which would come into effect under the proposed revisions to Regulation 308. A variety of techniques must be developed to cover the range of contaminants subject to regulation, and some existing techniques may require modification.

For one of the scenarios that was evaluated, the economic assessment concluded that the additional capital expenditures that would result for each of the first five years following implementation of the proposed revisions amount to $780 million. Additional operating and maintenance expenditures resulting from the proposed revisions would increase from a third to a half the level of capital expenditures during the five year period. The EPIM is used to evaluate the macroeconomic impact of the additional environmental protection expenditure resulting from

the proposed revisions to Regulation 308 for one of the first years following their implementation based on this scenario.

The analysis is complicated by two factors. First, the work completed to date on the economic assessment does not spell out how all the predicted expenditures are allocated to the various types of abatement and monitoring equipment. Second, there is as yet no information on how to allocate expenditures on the various types of equipment or their related operating and maintenance costs to the different commodity classes.

Total one-time capital expenditures of $780 million and total annual operating and maintenance expenditures of $285 million are used as input for the EPIM. Based on descriptions of the various pollution control devices likely to be used, the total one-time and annual expenditures are allocated arbitrarily to various commodity classes. Likewise, expenditures for products or services from an Ontario supplier are distinguished arbitrarily from those of unknown origin. The breakdown of total expenditures by commodity class and by origin of supplier is provided in Table 3.

The first section of Table 3 lists the commodity classes for which expenditures are assumed to be made on goods and services for which the origin of supply is uncertain. The second section lists the industries in Ontario which are assumed to supply the required environmental protection goods and services of known Ontario origin. The third section provides for direct employment of additional Ontario workers to meet the additional demands imposed by the proposed revisions.

The additional capital expenditures are indicated in the first column, while the additional operating and maintenance expenditures are provided in column two. The total GDP impact in column three of the Table is determined from the total expenditures for each commodity class and the GDP multiplier which corresponds to that class. The total employment impact of the expenditures, provided in column four, is derived from the

Table 3

EXAMPLE OF ECONOMIC IMPACT PROJECTIONS FROM THE EPIM

COMMODITY / INDUSTRY	ONE-TIME EXPENDITURE ($)	ANNUAL EXPENDITURE ($)	TOTAL GDP IMPACT ($)	TOTAL EMPLOYMENT IMPACT (person-years)
(1) IMPACT OF PURCHASE OF ENVIRONMENTAL PROTECTION GOODS/SERVICES (OF UNSPECIFIED ORIGIN)				
33. Other Textile Products	10,000,000	10,000,000	8,080,000	238
50. Boilers, Tanks and Plates	70,000,000	10,000,000	47,600,000	1,150
51. Fabricated Structural Metal Products	40,000,000	10,000,000	38,500,000	866
52. Other Metal Fabricated Products	50,000,000	10,000,000	35,760,000	840
54. Other Industrial Machinery	70,000,000	15,000,000	17,255,000	413
64. Industrial Chemicals		60,000,000	19,020,000	422
67. Other Chemical Products		60,000,000	26,820,000	596
68. Scientific Equipment	150,000,000	15,000,000	16,995,000	423
84. Business Services	25,000,000		19,125,000	665
Sub-total	415,000,000	190,000,000	229,155,000	5,612
(2) IMPACT OF PURCHASING GOODS/SERVICES FROM AN ONTARIO MANUFACTURING OR SERVICE FIRM				
20. Metal Fabricating (46-50)	70,000,000	15,000,000	72,360,000	2,088
28. Construction (70-73)	270,000,000	25,000,000	293,265,000	7,693
31. Electric Power, Gas (78,79)		20,000,000	14,085,000	282
38. Services to Business (44,84)	25,000,000	25,000,000	67,240,000	2,434
Sub-total	365,000,000	85,000,000	446,950,000	12,497
(3) IMPACT OF IN-HOUSE ENVIRONMENTAL PROTECTION EMPLOYMENT				
Services to Business		10,000,000	9,160,000	1,134
OVERALL TOTAL	780,000,000	285,000,000	685,265,000	19,243

total expenditures in the commodity class and from the employment multiplier corresponding to that class.

Environmental protection expenditures on goods and services of known Ontario are seen in Table 3 to have a greater impact on Ontario GDP and employment, as stated above, than in the case where the origin of goods and services supplied is unknown. Sensitivity analysis could be carried out to assess the impact on Ontario employment and GDP of a change in the proportion of goods and services known to be of Ontario origin as well as on the impact of reallocations of expenditures among the commodity classes. Because the initial allocation of expenditures is arbitrary, it was decided that such sensitivity analysis would not be particularly instructive for this exercise.

The overall total impact on Ontario GDP and employment, presented in Table 3, of the additional environmental protection expenditures suggests that a significant share of such expenditures would be retained in Ontario. It must be emphasized that the results presented here made no attempt to determine the extent to which firms' investment projects or output levels would be curtailed as a result of implementation of the proposed revisions to Regulation 308, thereby offsetting some of the impact of the additional expenditures. Neither was any consideration given here to the external benefits that would arise from abatement activities.

This work was not intended to provide a complete analysis of the economic impact of the proposed revisions to Regulation 308, but rather to indicate how the EPIM can be used as a tool in the analysis of new programs. As such, it appears that this model is able to provide a rough idea of the macroeconomic impact of new programs. However, additional work is necessary to make it easier to apply. The need for consideration of possibly offsetting factors, such as changes in firms' desired investment, production and employment levels, dictates that a good deal of thought must accompany the use of the EPIM if it is to be the primary tool for assessing regulatory changes or new programs.

REFERENCES

Corporate Policy and Planning (1986), "Environmental Expenditures by Governments in Ontario Which are Spent in the Private Sector." Toronto: Ontario Ministry of the Environment (working paper).

Glenn, William M. (1987a), *Environmental Protection Industry Inventory of Firms*. Don Mills, Ontario: Corpus Information Service of Southam Communications (mimeo).

Glenn, William M. (1987b), *Jobs and the Environment: Some Preliminary Number Crunching*. Don Mills, Ontario: Corpus Information Service of Southam Communications (mimeo).

Institute for Research on Public Policy (1987), *Defining the Environmental Protection Industry*. Toronto: Ontario Ministry of the Environment.

Laikin, Richard and Jack Donnan (1987), "Expenditures on Environmental Protection in Canada" in G.C. Ruggeri, editor, *The Canadian Economy: Problems and Policies*, third edition. Toronto: Gage Educational Publishing Company.

Ontario Ministry of the Environment (1987a), *Municipal-Industrial Strategy for Abatement (MISA): A Policy and Program Statement of the Government of Ontario on Controlling Municipal and Industrial Discharges into Surface Waters*. Toronto: Ontario Ministry of the Environment.

Ontario Ministry of the Environment (1987b), *Stopping Air Pollution at its Source*. Toronto: Ontario Ministry of the Environment.

VHB Research and Consulting Inc. (forthcoming), *Economic Assessment of Proposed Revisions to Regulation 308: Synthesis Report*. Toronto: Ontario Ministry of the Environment.

Woods Gordon Management Consultants (1988), *Study of the Ontario Environmental Protection Industry*. Toronto: Ontario Ministry of the Environment.

E9

Critique and Discussion
E. Cowan, Hickling Associates Ltd.

Examples of environmental-economic integration found in the papers which were presented in this session will be highlighted. Some examples will be drawn from the Speaker's own work concerning the economic impacts of environmental regulation. Changing attitudes and concerns on the part of business and industry with respect to environmental regulation will be discussed as well.

SESSION E

ENVIRONMENTAL ECONOMICS

Poster Presentations

EP1

TOWARDS A NEW ECONOMICS FOR SUSTAINABLE DEVELOPMENT. Tom Muir and Ray Rivers, Planning Division, Water Planning and Management Branch, Environment Canada, 867 Lakeshore Road Burlington, Ontario L7R 4A6, (416)-336-4951/336-4959.

The concept of sustainable development received widespread recognition following the publication of "Our Common Future" by the "World Commission on the Environment" headed by Norwegian Prime Minister Gro Harlem Brundtland in April 1987. Sustainable development addresses changes in the way society does business and how those business transactions are rendering the global environment unusable for future generations.

The problem of long term sustainability is largely a problem of the timing and nature of economic development decisions. Classical economists did not consider time in a biological or historical sense and consequently time that mattered was present time and value that mattered was present value. The idea that human activity could reach an intensity that altered the global environment, and be itself altered in turn, was not even considered by most mainstream economists. Frontier exploitation had engendered an attitude that the answer to resource availability was appropriate pricing. Adequate relative marginal pricing, it was believed, would ensure an optimal allocation of resources forever.

Time was viewed as a constraint to production that should be minimized. Thus, preferred costs were those of tomorrow and preferred benefits were those of today. Society's time preference - the utility associated with inter-temporal distributions of income and wealth - was deemed to be non-linear and benefits further out into the future were always worth less. Endowments and bequests for future generations were not considered since there appeared to be an inexhaustible supply of under-exploited resources and new technology to extract these resources.

Benefit cost analysis has been the single most powerful formalized public and private sector criterion used for evaluating growth and development decisions. The technique is essentially an accounting framework of comparing future benefits of investment decisions against the, traditionally current, costs of the investment. One of the most desirable aspects of the technique had been the way in which benefits and cost cash flows are discounted and aggregated over time to produce a net present value of an investment. The relative simplicity by which decisions could be made today for investments spanning several years had elevated benefit cost analysis to statutory and regulatory acceptability in North America.

The aggregation of benefit and cost streams over different time periods is rationalized by use of a discount rate. The selection of the ideal rate is based on the notion of societal time preference. Private sector business decisions generally are based on positive discount rates that reflected the opportunity cost of capital in money and other financial markets. Public investments decisions have usually been set on the same

basis although these discount rates are supposed to reflect the social opportunity cost of capital. The Treasury Board of Canada produced a guide to benefit cost analysis that suggested sensitivity analysis of discount rates at 5%, 10% and 15%.

The Brundtland Commission has laid to rest several of the key assumptions of the traditional approach to investment decision making. High discount rates which favour consumption today over consumption tomorrow are no longer acceptable if this planet, as we know it, is to survive. The prospect of unpredictable climate changes, as a result of the impending so-called "greenhouse effect" will alter our view on the roles of commerce and industry in the economy. The destruction of the natural processes on earth by the presence of toxic contaminants, the impacts of acid rain and the degradation of the protective ozone layer are social costs of economic development that were not internalized into the benefit cost analyses. These effects have bequeathed an enormously costly legacy for future generations. However, even had classical benefit cost analysis incorporated these externalities, the use of positive discount rates would have made these social costs appear trivial.

Accounting, as opposed to discounting, of social costs to a future value would better illustrate the importance of some of the major externalities from development initiatives like those related to non-renewable natural resources or human health. For example, at a 5% accounting rate, 1 chemically induced cancer today would be valued the same as 1730 cases occurring in 200 years, or more than 3 billion in 450 years. The application of traditionally discounting can make such ethically unacceptable inter-generational effects appear acceptable. In the final analysis, the discount rate issue should be more of an ethical, than a technical, problem that transcends purely economic perspectives.

The endorsement by governments of the concept of sustainable development involves "... meeting the needs and aspirations of the present generation without compromising the ability of future generations to meet their needs." In this view, taken from "Our Common Future", future generations are placed on an equal footing with the present generation. The discount rate should be no greater than zero. Moreover, if sustainable development is also "... a form of progress for social and economic development that enhances the resource-base rather than degrades it", there is a rationale for negative discount rates.

Conservation can be seen as the necessary discipline of exploitation. It provides a practical definition of economic and ecological responsibility, or a definition of limits within which such responsibility can be conceived and enacted. It acts as a form of time delay, and is a primary means for slowing down the rate of change, providing stability or homeostasis and decreases in the intensity of uncertainty.

Conservation generally reduces the dissipation or entropy of enterprise. This reduces overhead in the longer run which improves

economic performance and survival. Conservation implies a negative long term discount rate since it reduces the material degradation per unit time (entropy production) caused by exploitation and dissipation of real resources. These latter factors, in turn, accelerate irrevocable change that intensifies uncertain states of mind. This can lead to a vicious circle of exploitation since uncertainty is often used as a rationale for short time horizons and high discount rates.

In order that conservation be integrated with exploitation such that future generations are considered as equals, the discount rate would need to be no greater than zero. Alternatively, and perhaps in addition, there would need to be an ecological constraint to ensure sustainability. Evolutionary adaptation, or survival, depends on this integration.

Long run competitive advantage and environmental quality can be achieved and enhanced by converting resources, cleanly and completely, to products for sale and by subsequently recycling, recovering and reusing those same products. Unfortunately short time horizons and desires for quick returns, with their high implicit discount rates, lead to bias against the necessary corporate cost structures to realize these profit opportunities. Benefit streams from saving, made possible through conservation, despite having a practically infinite life as a source of cash flow, are rarely considered in investment decisions. One of the practical effects of high discount rates is the neglect of these relatively small but long-lived benefit streams in favour of bigger and usually less environmentally benign investments.

EP2

The Environmental Effects of Timber Management in Ontario by Julian A. Dunster Ph.D., R.P.F. Forestry Consultant, The Federation of Ontario Naturalists

Following an extensive review of several aspects of timber management in Ontario, the Federation of Ontario Naturalists is now preparing a final report in which the environmental effects of timber management are discussed and elaborated. The report will include discussions of how the environmental effects of timber management affect long term sustainability of timber production, non-timber values, such as the flora and fauna of terrestrial and aquatic habitats, and the economic and socio-economic implications of timber management in a local and regional context.

Initial indications highlight the absence of adequate data bases in Ontario, a problem particularly evident in the delineation and description of non-timber values and their relationship to timber management activities. There seems to have been very little research on the effects of timber management on non-game animals, water quality, and the distribution of critical habitats for a range of flora and fauna. There is considerable debate about which logging techniques are best or better, and although some research has been undertaken, very few of the results have yet been correlated with site productivity and the need to manage the forested land base for long-term sustainability. Many of the economic analyses traditionally used in timber management appear to be too narrow in focus and premised on faulty assumptions that have limited validity in a broader context of integrated resource management.

Overall, the research results tend to indicate that Ontario has not yet conducted enough research work to pronounce the environmental effects of timber management operations as insignificant. Indeed, the results suggest that some of the effects may be very significant for a wide spectrum of users and users of the forst, including the potential for sustained production of wood fibre at an economically and environmentally justifiable price. The final report, anticipated in Spring 1989, will tie together many of these factors and attempt to present a synthesis of what has been achieved and still remains to be done.

INDICES LISTED FOR REFERENCE

Abstract

SESSION A: AIR QUALITY RESEARCH

Oral Presentations

A1 **Science and Policy: PhotoChemical Oxidants and Acid Bearing Species** K. L. Demerjian, Atmospheric Science Research Center, State University of New York, Albany, New York, U.S.A.

A2 **Relationship Between Forest Decline and Root Health in Ontario Sugar Maple** C. Adams, M. Egyed and T. Hutchinson*, Dept. of Botany, University of Toronto, Toronto, Ontario.

A3 **A Numerical Decline Index Rating System to Monitor Changes in Tree Condition of Hardwood Forest Species** D. McLaughlin*, W. McIlveen, W. Gizyn, D. Corrigan, R. Pearson and R. Arnup, Air Resources Branch, Environment Ontario

A4 **Investigation of Short-term Mutagenicity and Chemical Composition of Organic Solvent Extractable Fraction of Coke Oven Emission** A. J. Horton*, N. Belson, K. Shaw and G. H. Thomas, Ontario Research Foundation, Clarkson, Ontario

A5 **Quantitative Measurements of the Genetic Effects of Inhaled Carcinogens in Pulmonary Fibroblasts are Now Possible** J. A. Heddle*, A. Bouch and J. D. Gingerich, Dept. of Biology, York University, Downsview, Ontario

A6 **Sensitivity of Asthmatic Children to Air Pollution;** D. Pengelly* and C. Goldsmith, McMaster University, Hamilton, Ontario

A7 **Hazardous Contaminants in Ontario: Environmental Fate and Human Exposure** D. Mackay* and S. Paterson, Institute for Environmental Studies, University of Toronto, Toronto, Ontario

Abstract

SESSION A: AIR QUALITY RESEARCH

Oral Presentations

A8 **Verification of the Cloud and Wet Deposition Fields of a MesoScale Model of Long-Range Transport of Air Pollutants** H.R. Cho*, S.T. Soong and J.V. Iribarne, Department of Physics, University of Toronto, Toronto, Ontario

A9 **Eulerian Model Evaluation** M. Alvo, Department of Mathematics, University of Ottawa, Ottawa, Ontario

A10 **Scale Model Studies and Development of Prediction Procedures for Heavy Gas Dispersion in Complex Terrain 1988** P. A. Irwin*, M.C. Murphy and K. C. Heidorn, Rowan Williams Davies and Irwin Inc., Guelph, Ontario

A11 **An Investigation of Wind Generated Particle Transport Rates within a Turbulent Boundary-Layer** A.D. Ciccone*, J.G. Kawall and J.F. Keffer, Department of Mechanical Engineering, University of Toronto, Toronto, Ontario

A12 **Incineration of Wastes** K. Davies, Environmental Protection Office, City of Toronto, Toronto, Ontario

A13 **Detectability of Step Trends in the Rate of Atmospheric Sulphate Deposition** E.A. McBean*, M.G. Kompter and G.J. Farquhar, Department of Civil Engineering, University of Waterloo, Waterloo, Ontario

A14 **Incinerator and Steel Plant Contributions to Air Particulates as Determined by Size-Specific Receptor Modelling** A.C. Chan*, Z-J. Kang and R.E. Jervis, Dept. of Chemical Engineering, University of Toronto, Toronto, Ontario

Abstract

SESSION A: AIR QUALITY RESEARCH

Oral Presentations

A15 **A Study on the Sources of Acid Precipitation in Ontario, Canada** P.K. Hopke* and Y. Zeng, Department of Civil Engineering, University of Illinois, Urbana, Illinois, U.S.A.

A16 **Advanced Techniques for Mobile Monitoring of Trace Organics in Air** G.B. De Brou*, E. Singer, M.A. Sage, R.W. Bell, R.E. Chapman and D.J. Ogner, Air Resources Branch, Environment Ontario

A17 **Atmospheric Trace Gas Measurements Using a Tunable Diode Laser Absorption Spectrometer** D.R. Hastie* and H.I. Schiff, Department of Chemistry, York University, Downsview, Ontario

A18 **Biomedical Waste Incineration Testing Program** V. Ozvacic*, G. Wong, G. Marson, R. Clement, D. Rokosh, S. Suter, G. Horsnell, J.C. Hipfner, S. Burns and H. Corinthios, Environment Ontario

A19 **A Study of High Temperature Photochemical Kinetics of Sulphur Dioxide and Nitrogen Oxides For a Flue Gas Treatment Process** J. Hunt*, P. Fellin, K.A. Brice, D. Ernst, D. Glendenning and R. Caton, Concord Scientific, Toronto, and C. Fung and K. Smith, Environment Ontario

A20 **Modelling the Photochemical Decomposition of Chlorinated Phenols by Sunlight** N.J. Bunce* and J.S. Nakai, Dept. of Chemistry and Biochemistry, University of Guelph, Guelph, Ontario

Abstract

SESSION A: AIR QUALITY RESEARCH

Poster Presentations

AP1 **Stochastic Modelling of Dispersion from Single Elevated Sources** E. Robertson and P. J. Barry, Atomic Energy of Canada Limited, Chalk River Nuclear Laboratories, Chalk River, Ontario

AP2 **Feasibility Study for Assessing and Modelling Microclimatic Conditions on the Fonthill Kame (Phase 1)** T. B. Shaw, Brock University, St. Catharines, Ontario

AP3 **Critical Evaluation of Atmospheric Pollutant Parameterization from Satellite Imagery** N. T. O'Neill, A. Royer and L. Hubert, Universite de Sherbrooke, Sherbrooke, Quebec, and J. Miller and J. Freemantle, CRESS, York University, Downsview', ', Ontario, and G. Austin and A. Davis, McGill

AP4 **A 3-D Mesoscale Wind Field Model and its Application for Emergency Planning at Nuclear Power Plants in Ontario**
H. Sahota, P.K. Misra, R. Bloxam and D. Rhee, Air Resources Branch, Environment Ontario

AP5 **The Results from a Meso-scale Model** M. Niewiadomski, University of Toronto, Toronto, Ontario

AP6 **Dose Response for Selected Environmental Air Pollutants: Results from a Study on Runners** R. B. Urch, F. Silverman, P. Corey and R. J. Shephard, The Gage Research Institute, University of Toronto, Toronto, Ontario

Abstract

SESSION A: AIR QUALITY RESEARCH

Poster Presentations

AP7 **Hamilton Air: Chemical Composition and Genotoxic Activity of Respirable Particulate and Organic Vapours** D.W. Bryant, C. Kaiser-Farrell and D.R. McCalla, Department of Biochemistry, McMaster University, Hamilton, Ontario

AP8 **Mutagenicity Studies and Risk Estimation of Complex Mixtures of Organic Airborne Contaminants** A.S. Raj and D.M. Logan, Department of Biology, York University, Downsview, Ontario

AP9 **In-Situ Monitoring of the Environment for Genotoxicity Levels Using Rodents** M. Petras, M. Vrzoc, S. Meddins, K. Hill and T. Sands, Department of Biological Sciences, University of Windsor, Windsor, Ontario

AP10 **Method Development for the Monitoring and Analysis of Odorous Organics in Ambient Air** C.C. Chan, L. Vainer and J.W. Martin, Mann Testing Laboratories Ltd., Mississauga, Ontario, and A. Szakolcai and B. Foster, Environment Ontario

AP11 **Gas Phase Analysis of Organic Compounds from Structural Domain Modulation within Flourescent Lipid Multilayers** U.J. Krull, R.S. Brown and K. Stewart, Department of Chemistry, Erindale Campus, University of Toronto, Mississauga, Ontario

AP12 **Atmospheric Measurements of Natural Hydrocarbons Using Gas Chromatography/Mass Spectrometry** H. Niki and B.H. Khouw, Department of Chemistry and Centre for Atmospheric Chemistry, York University, Downsview, Ontario

Abstract

SESSION A: AIR QUALITY RESEARCH

Poster Presentations

AP13 **Utilization of Established Air Pollution Monitoring Networks in Ontario Following Nuclear Incidents** J. A. Slade and G. Laszlo, Radiation and Industrial Safety Branch, Atomic Energy of Canada Limited, Chalk River, Ontario

AP14 **A Re-Examination of Ontario's 24 Hour Ambient Air Quality Criterion for Hydrogen Fluoride** R. D. Jones and D. S. Harper, Air Resources Branch, Environment Ontario

AP15 **Production of Ozone-insensitive White Bean Varieties** T. E. Michaels, Department of Crop Science, University of Guelph, Guelph, Ontario

AP16 **Efficacy of Film-forming Chemicals for Protecting Roadside Trees Against Salt Spray** C. Chong, Ministry of Agriculture and Food, Horticultural Research Institute of Ontario, Vineland Station, Ontario

AP17 **An Evaluation of the Problems of Particulate Emission from the Wood Products Industry** M. F. Lepage and A. E. Davies, Rowan Williams Davies & Irwin Inc., Guelph, Ontario

AP18 **Relationship of Sugar Maple Decline and Corresponding Chemical Changes in Xylem Sap Carbohydrates, Micronutrients and Trace Elements** S. N. Pathak, T. Hutchinson and D. N. Roy, Department of Forestry, University of Toronto, Toronto, Ontario

AP19 **Identification of Long Range Aerosol Sources at the Dorset Environment Station** J. Drake, A. Kabir and S. Vermette, Department of Geography, McMaster University, Hamilton, Ontario

Abstract

SESSION B: WATER QUALITY RESEARCH

Oral Presentations

B1 **Aquatic Biology in the New Regulatory Framework** K. Day, National Water Reseach Institute, Burlington, Ontario.

B2 **Hypothesis Testing in Aquatic Toxicology: QSAR Relationships and Simple Kinetic Modelling** L. S. McCarty*, University of Waterloo, Waterloo, Ontario, G. W. Ozburn and A. D. Smith, Lakehead University, Thunder Bay, Ontario.

B3 **Variations in the Response of Fish Population Characteristics to Environmental Changes** K. R. Munkittrick* and D. G. Dixon, Department of Biology, Universityof Waterloo, Waterloo, Ontario.

B4 **An Examination of Chronic Toxicity of Thiocyanate to Freshwater Fish for the Development of a Water Quality Criterion** D. G. Dixon, R. P. Lanno* and S. D. Kevan, University of Waterloo, Waterloo, Ontario.

B5 **Potential Role of Polycyclic Aromatic Hydrocarbons in the Development of Liver Tumors in Fish from Polluted Sites of Lake Ontario** G. M. Kirby, I. R. Smith, C. Thorn, H. W. Ferguson and M. A. Hayes*, Univeristy of Guelph, Guelph Ontario.

B6 **Plant Bioassays for the Detection of Environmental Mutagens in an Aquatic Environment** W. F. Grant, Department of Biology, York University, Downsview, Ontario.

B7 **Effects of Temperature and Field Procedures on PCB Bioaccumulation in Elliptio Complanata** A. Melkic* and Y. Rollin, Intergrated Explorations, Guelph, Ontario.

Abstract

SESSION B: WATER QUALITY RESEARCH

Oral Presentations

B8 **Biomonitoring: Chemical Dependent Quantitative Relationships for the Body Burdens of Organic Chemicals in Aquatic Biomonitors** F. Gobas*, R. Russell and G. Haffner, Great Lakes Institute, Univerisity of Windsor, Windsor, Ontario.

B9 **Biomonitoring Protocols for Adult Aquatic Insects: Seasonal Availability, Sample Size and Sensitivity** Z. E. Kovats and J. J. H. Ciborowski*, Dept. of Biological Sciences, University of Windsor, Windsor, Ontario.

B10 **An Ecosystem Approach to the Monitoring of PCB's in Pristine Ontario Lakes** C. D. Metcalfe* and C. R. Macdonald, Trent University, Peterborough, Ontario.

B11 **Metal Contamination of Wetland Foodchains in the Bay of Quinte, Ontario** A. Crowder*, W. Dushenko and J. Greig, Dept. of Biology, Queen's University, Kingston, Ontario.

B12 **An Overview of Aquatic Environmental Research in Quebec** M. Slivitsky, INRS-EAU, Ste. Foy, Quebec.

B13 **Development of an Improved System for the Application of Powdered Activated Carbon in Water Treatment Plants** H. Donison*, A. Benedek and J. J. Bancsi, Zenon Environmental Inc., Burlington, Ontario.

B14 **Municipal Utilization of Water Demand Management Strategies in Ontario Municipalities** R. D. Kreutzwiser* and R. B. Feagan, Dept. of Geography, University of Guelph, Ontario.

Abstract

SESSION B: WATER QUALITY RESEARCH

Oral Presentations

B15 **A Preliminary Study to Determine the Feasibility of Medium Pressure Mercury Lamps for Disinfecting Low Quality Wastewaters** G.E. Whitby and G. Sakamoto, Trojan Technologies Inc., London, Ontario, and G. Palamateer*, Envioronment Ontario.

B16 **Characterization of the Fecal Indicator Bacterial Flora of Sanitary Sewage with Application to Identifying the Presence of Sanitary Waste in Storm Sewers** P.L. Seyfried*, T. Bleier, Y. Xu and R. Harmandayan, University of Toronto, Toronto, Ontario.

B17 **Landsat-5 TM Spectral Responses for Lakes Across Northeastern Ontario** J.R. Pitblado, Geography Department, Laurentian University, Sudbury, Ontario.

B18 **Relationship of Mercury Levels in Sportfish with Lake Sediment and Water Quality Variables** C.D. Wren, B.A.R. Environmental, Quelph, Ontario.

B19 **Trend Analysis Procedures for Water Quality Time Series** A.I. McLeod*, and K.W. Hipel, McLeod-Hipel Associates Ltd., London, Ontario and B. Bodo, Environment Ontario.

B20 **Use of a Bromobenzoate for Cross-Adaptation of Anaerobic Bacteria in Lake Ontario Sediments for Biodegradation of Chlorinated Aromatics** M. Urbanek*, T. Strycek, R.C. Wyndham and M. Goldner, University of Toronto, Toronto, Ontario.

Abstract

SESSION B: WATER QUALITY RESEARCH

Poster Presentations

BP1 **The Effects of Agricultural Drainage on Sediment and Water Quality Loadings** W.E. Watt, Department of Civil Engineering, Queen's University, Kingston, Ontario.

BP2 **WATQUAS 2.0: An Expert System for the Water Quality Assessment of Ontario Rivers** W.C. Allison and T.E. Unny, Department of Civil Engineering, University of Waterloo, Waterloo, Ontario, and L. Logan, Environment Ontario.

BP3 **Geochemical Characterization, Size Fractionation and Bioavailability of Trace Metal Particulate Associations in the Don River** L. Warren and A.P. Zimmerman, Department of Zoology, University of Toronto, Toronto, Ontario.

BP4 **The Investigation, Evaluation and Recommendation of Biomonitoring Organisms for Procedures Development for Environmental Monitoring** C.A. Jefferson, Curry-Jefferson Environmental Services, Port Perry, Ontario.

BP5 **The Ontario Inland Lakes Program and Management of Blue-Green Algae: Three Whole Lake Treatments in 1988** H. Vandermeulen and K.H. Nicholls, Water Resources Branch, Environment Ontario.

BP6 **Characterization of the Grazing Fauna Within Five Softwater Lakes With Respect to Accumulations of Metaphytic Filamentous Algae** P.M Stokes, E.T. Howell and R.L. France, Institute for Environmental Studies, University of Toronto, Toronto, Ontario.

Abstract

SESSION B: WATER QUALITY RESEARCH

Poster Presentations

BP7 **Sedimentary Chrysophycean Cyst Assemblages as Paleoindicators in Acid Sensitive Lakes** M. Rybak and I. Rybak, ARECO Canada Inc., Ottawa, Ontario, and K. Nicholls, Environment Ontario.

BP8 **Factors Regulating Contaminant Levels In Forage Fish Species** C.E. Herbert and G.D. Haffner, Great Lakes Institute, University of Windsor, Windsor, Ontario.

BP9 **The Isotopic Composition of Upland Forest Soil Sulphate** D.R. Van Stempvoort and P. Fritz, Department of Earth Science, University of Waterloo, Waterloo, Ontario.

BP10 **Recent Trends and Historical Changes in Water Quality of Lake Muskoka** M. Rybak and I. Rybak, ARECO Canada Inc., Ottawa, Ontario, and K. Nicholls, Environment Ontario.

BP11 **In-Situ Determination of Fecal Indicator Bacterial Survival in Agriculturally-Impacted Watersheds** M.J. Walters, Lake Simcoe Region Conservation Authority, Newmarket, Ontario.

BP12 **Development of an Acute and Chronic Sediment Bioassay Protocol Using Larval Mayflies and Juvenile Fathead Minnows** G. Krantzberg and R. Pope, University of Toronto, Toronto, Ontario.

BP13 **Three Hour Pulse Exposure of Potassium Thiocyanate to Rainbow Trout Eggs Before and After Water Hardening** S. Kevan And G. Dixon, University of Waterloo, Waterloo, Ontario.

Abstract

SESSION C: LIQUID AND SOLID WASTE RESEARCH

Oral Presentations

C1 **An Overview of Hydrogeological Aspects of Waste Disposal: Research Results and Implications** J. Cherry, Waterloo Centre for Groundwater Research, University of Waterloo, Waterloo, Ontario.

C2 **Immiscible Liquids and Vapours in Soil: Recent Experiments on Transport and Control** G. Farquhar*, R. Bensen, D. Graham, E. McBean and B. Stickney, Dept. of Civil Eng., University of Waterloo, Waterloo, Ontario.

C3 **Effects of Increasing Amounts of Non-polar Organic Liquids in Domestic Waste Leachate on the Hydraulic Conductivity of Clay Liners in Southern Ontario** F. Fernandez* and R. M. Quigley, University of Western Ontario, London, Ontario.

C4 **Technology Review: Biological Treatment of Hazardous Landfill Leachates** J. Fein*, and P. Yu, Diversified Research Laboratories Ltd., Toronto, Ontario.

C5 **Phase Partitioning Kinetics at Industrial Waste Land Treatment Sites** D. Hockley and W. J. Snodgrass*, Beak Consultants, Toronto, Ontario.

C6 **Preliminary Assessment of a Microfiltration/Reverse Osmosis Process for the Treatment of Landfill Leachate** T. A. Krug* and S. McDougall, Zenon Environmental Inc., Burlington, Ontario.

C7 **Anaerobic Treatment of Landfill Leachate** G. P. Vicevic*, B. J. Forrestal and A. Stevenson, Ontario Research Foundation, Clarkson, Ontario.

Abstract

SESSION C: LIQUID AND SOLID WASTE RESEARCH

Oral Presentations

C8 **The Origin and Distribution of Methane in the Alliston Sand Aquifer** R. Aravena*, J. Barker, M. Bliss and L. Wassenaar, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario.

C9 **The Carbon and Sulfur Cycle in Shallow Unconfined Aquifer Systems** L. I. Wassenaar*, R. Aravena, R.W. Gillham, J. Barker and P. Fritz, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario.

C10 **Determination of Organic and Inorganic Contaminants in the Welland River** I.D. Brindle*, A.W. Chu and X-f Li, Chemistry Department, Brock University, St. Catharines, Ontario.

C11 **Research and Development of Permanent On-site Solutions for Contamination of Groundwater at Waste Disposal and Industrial Sites in Canada** R.J. Rush, CANVIRO Consultants, Kitchener, Ontario.

C12 **The Role of Groundwater in Human Society** R.N. Farvolden, Waterloo Centre for Groundwater Research, University of Waterloo, Waterloo, Ontario.

C13 **Dispersion of the Stouffville Landfill Plume** I. Proulx* and R.N. Farvolden, Waterloo Centre for Groundwater Research, University of Waterloo, Ontario.

C14 **Comparison of an Experimental Municipal Refuse Column Study with Landfill Field Test Cells** S. Pirani and D.W. Kirk*, Dept. of Chemical Engineering, University of Toronto, Toronto, Ontario.

Abstract

SESSION C: LIQUID AND SOLID WASTE RESEARCH

Oral Presentations

C15 **An Alternative to Incineration of Biomedical Waste: Hammermill/Chemical Decontamination** J. Manuel, Waste Management Branch, Environment Ontario.

C16 **Erosion of Landfill Covers** J. Cuthill*, Department of Land Resource Science, University of Guelph, Guelph, Ontario, and K. McKague, Ecologistics Ltd., Waterloo, Ontario.

C17 **Development of Backfill and Construction Application Guidelines for Ontario** M. Kelleher* and B. Whiffin, CANVIRO Consultants, Mississauga, Ontario.

C18 **Panel Discussion: Stemming the Rising Tide of Waste**
Moderator: D. Mackay, University of Toronto

Abstract

SESSION C: LIQUID AND SOLID WASTE RESEARCH

Poster Presentations

CP1 **Retractable Composite Absorbents for Environmental Clean-up** B. Gillies, E. Stubley, I. Treurnicht and L. Read, EcoPlastics Ltd. Willowdale, Ontario and O. Meresz, Laboratory Services Branch, Environment Ontario.

CP2 **Treatment and Disposal of Hauled Sewage Under ', 'Part VII, Environmental Protection Act** J.L. Smith, Oliver, Mangione, McCalla & Associates Limited, Nepean, Ontario.

CP3 **Factors Affecting the Concentration of Metal Ions in Municipal Refuse Leachate** G. Kosta, S. Pirani and D. Kirk, Department of Chemical Engineering and Applied Chemistry, University of Toronto, Toronto, Ontario.

CP4 **Slow Rate Infiltration Land Treatment and Recirculation of Landfill Leachate in Ontario** R. A. McBride, A.M. Gordon, P.H. Groenevelt, T.J. Gillespie and L.J. Evans, Departments of Land Resource Science and Environmental Biology, University of Guelph, Guelph, Ontario.

CP5 **Establishing Vegetation on Erosion-prone Landfill Slopes in Ontario, Year Two** T.W. Hilditch and C.P. Hughes, Gartner-Lee Ltd., Markham, Ontario.

CP6 **Evaluating Groundwater Velocity in a Low-Permeability Fractured Shale** K.S. Novakowski and J.A. Cherry, Centre for Groundwater Research, University of Waterloo, Waterloo, Ontario.

Abstract

SESSION C: LIQUID AND SOLID WASTE RESEARCH

Poster Presentations

CP7 **The Design and Evaluation of In-Situ Biorestoration Methods for the Treatment of Sludges and Soils at Waste Disposal Sites** K.L. Berry-Spark and J.F. Parker, Centre for Groundwater Research, University of Waterloo, Waterloo, Ontario.

CP8 **Enhanced Biodegradation of Aromatic and Chlorinated Aliphatic Compounds in a Leachate-Impacted Aquifer** -D.W. Acton, M. Shaw, J.F. Barker, C.I. Mayfield and J.A. Cherry, Univeristy of Waterloo, Waterloo, Ontario.

CP9 **Waste Management Planning for Pharmaceutical Industry** R. Staris and R. Makhija, Trent University, Peterborough, Ontario.

Abstract

SESSION D: ANALYTICAL METHODS

Oral Presentations

D1 **Analytical Chemistry in a Regulatory Environment** R. Kagel, Dow Chemicals, Midland, Michigan, U.S.A.

D2 **Adaptation of Water Preconcentration Techniques Developed for PCDD Analysis to Other Target Organic Pollutants.** E. Dowdall*, B.R. Hollebone, L. Brownlee and C. Shewchuk, Carleton University, Ottawa, Ontario.

D3 **The Purpose and Significance of Ultratrace Analysis of Dibenzo-p-Dioxins: The Concept of Risk** L. Brownlee* and B.R. Hollebone, Chemistry Department, Carleton University, Ottawa, Ontario.

D4 **Procedures for the Analysis of 2,3,7,8-Substituted PCDD & PCDF Isomers and Other Target Compounds in Environmental Samples** F.W. Karasek*, T.S. Thompson and K.P. Naikwadi, University of Waterloo, Waterloo, Ontario.

D5 **The Closed-Loop Stripping Technique, Applied to Potable Water to Solve Taste and Odour Problems** J.P. Palmentier*, D. Robinson and V. Taguchi, Laboratory Services Branch, Environment Ontario.

D6 **Solid Supported Processes in Environmental Analysis** J.M. Rosenfeld, Department of Pathology, McMaster University, Hamilton, Ontario.

D7 **Synthesis and Use of Liquid Crystalline Polysiloxane Substrate in Capillary Column GC-MS for Isomer Specific Separation of Toxic Isomers of PCDD and PCDF** K.P. Naikwadi* and F.W. Karasek, University of Waterloo, Waterloo, Ontario.

Abstract

SESSION D: ANALAYTICAL METHODS

Oral Presentations

D8 **Development of Mobile Infrared Spectroscopy for On-site Speciation of Organic Wastes** P. Yang* and J. Osborne, Laboratory Services Branch, Environment Ontario.

D9 **Mobile Laboratory: On the Development and Real World Application Aspects** D. Toner*, B. Dalton, D. Morse, K. Hom, P. Yang and J. Osborne, Laboratory Services Branch, Environment Ontario.

D10 **Regiospecific Synthesis of All Isomeric Nitrofluorenones and Nitrofluorenes by Transition Metal Catalyzed Cross Coupling Reactions** V. Snieckus*, T. Iihama, J.-m Fu and M. Bourguignon, University of Waterloo, Waterloo, Ontario.

D11 **Preparation of Heterocyclic Polynuclear Aromatic Compounds as Analytical Standards** E. Lee-Ruff*, B.E. George, F.J. Ablenas and Y.S. Chung, Department of Chemistry, York University, Downsview, Ontario.

D12 **Application of ICP Spectrometry in Health and Environment: A Case Study of Soil Ingested by Children** R. Barnes, University of Massachusetts, Amherst, Massachusetts, U.S.A.

D13 **Direct Sample Insertion into an Inductively Coupled Plasma for Atomic Emission and Mass Spectrometry** L. Blain* and E.D. Salin, Department of Chemistry, McGill University, Montreal, Quebec.

Abstract

SESSION D: ANALYTICAL METHODS

Oral Presentations

D14 Analysis of Germanium and Tin by Hydride Generation D.C. Plasma Atomic Emission Spectrometry: Application to Determinations of Germanium and Tin in Air Filters I.D. Brindle*, B. Buchanan and X-c. Le, Brock University, St. Catharines, Ontario.

D15 Use of the Hot Slurry Technique for Solid Sample Introduction for ICP-AES L. Gervais* and E.D. Salin, Department of Chemistry, McGill University, Montreal, Quebec.

D16 Advanced Technology for Destruction of Waterborne Organic Pollutants H. Al-Ekabi* and M. Robertson, Nulite, A Division of Nutech Energy System Inc., London, Ontario.

D17 Development of ACexpert 2: Implementation of an Expert System for Automated Metal Analysis by Atomic Absorption Spectroscopy M.J. Stillman*, T.A. Cox and W.R. Browett, University of Western Ontario, London, Ontario.

D18 Adaptation of Water Preconcentration Techniques of Trace Metal Detection K.L. Singfield*, B.R. Hollebone, L.J. Brownlee, Dept. of Chemistry, Carleton University, Ottawa, Ontario, and P. Vijan, Environment Ontario.

D19 Comparison of Various Leachate Extraction Procedures for the Characterization of Inorganics in Wastes J.R. Kramer*, P. Brassard, J. Gleed and P.V. Collins, Department of Geology, McMaster University, Hamilton, Ontario.

Abstract

SESSION D: ANALYTICAL METHODS

Oral Presentations

D20 **2,4-Dichlorophenoxylacetic Acid (2,4-D) Determination in Water, Urine and Soil Extracts by Enzyme Immunoassay (EIA) and Radioimmunoassay (RIA)**
J.C. Hall* and K. Krieg, Dept. of Environmental Biology, University of Guelph, Guelph, Ontario.

Abstract

SESSION D: ANALAYTICAL METHODS

Poster Presentations

DP1 **Derivatization of Acidic Organic Compounds Using Phase Transfer Catalysis** V.Y. Taguchi and O.W. Berg, Laboratory Services Branch, EnvironmentOntario.

DP2 **New Chemical Ionization Reagents Directed Toward Mass Spectrometric Analysis of Trace Organics** T.B. McMahon, K. Froese and C.E. Allison, Department of Chemistry and Guelph-Waterloo Centre for Graduate Work in Chemistry, University of ','Waterloo, Waterloo, Ontario.

DP3 **An Interrupted Segemented Flow Stream Microwave','Solid Sample Decomposition for ICP-AES** E.D. Salin And B. Liu, Department of Chemistry, McGill University, Montreal, Quebec.

DP4 **Solid Phase Extraction of PAH's From Drinking Water and Analysis of Chlorophenols and Phenoxy-acid Herbicides in Water** W.G. Craig and C.D. Hall, Paracel Laboratories Ltd., Nepean, Ontario.

DP5 **Automated Water Preconcentration Sampler for Dioxin Detection at the Parts Per Quadrillion Level** C. Shewchuk, B. Hollebone, L. Brownlee and E. Dowdall, Carleton University, Ottawa, Ontario, and R. Hunsinger, M. Uza, H. Tosine and S. Suter, Environment Ontario.

DP6 **Automated HPLC Method for Low Level Polynuclear','Aromatic Hydrocarbon (PAH) Analysis of Drinking Water** P.W. Crozier and C.D. Hall, Laboratory Services Branch, EnvironmentOntario.

Abstract

SESSION D: ANALYTICAL METHODS

Poster Presentations

DP7 **Supercritical Fluid Extraction of Trace Organics From Solid Matrices** P. Kruus and R. C. Burk, Department of Chemistry, Carleton University, Ottawa, Ontario and G. Crawford, Laboratory Services Branch, Environment Ontario.

DP8 **Automated Sample Introduction and Pre-treatment', 'with Flow Injection ICP-ES** J.F. Hopper, F. Mo and D.W. Boomer, Laboratory Services Branch, Environment Ontario.

DP9 **Applications of Flow Injection Technology to ICP-MS** M.J. Powell, J.F. Hopper and D.W. Boomer, Laboratory Services Branch, Environment Ontario.

DP10 **Investigation of the In-Situ Acetylation Process and its Applicability to the Analysis of a Wide Range of Phenolic Compounds in Water** R. Lega, O. Meresz and M. Savu, Laboratory Services Branch, Environment Ontario.

DP11 **Robustness of the Student's T-test with Censored Environmental Quality Data** E.E. Creese, Creese Environmental Consulting, Waterloo, Ontario.

DP12 **Automation of Solid Supported Reactions by Robotics** J.M. Rosenfeld and E. Pevolinas, McMaster University, Hamilton, Ontario.